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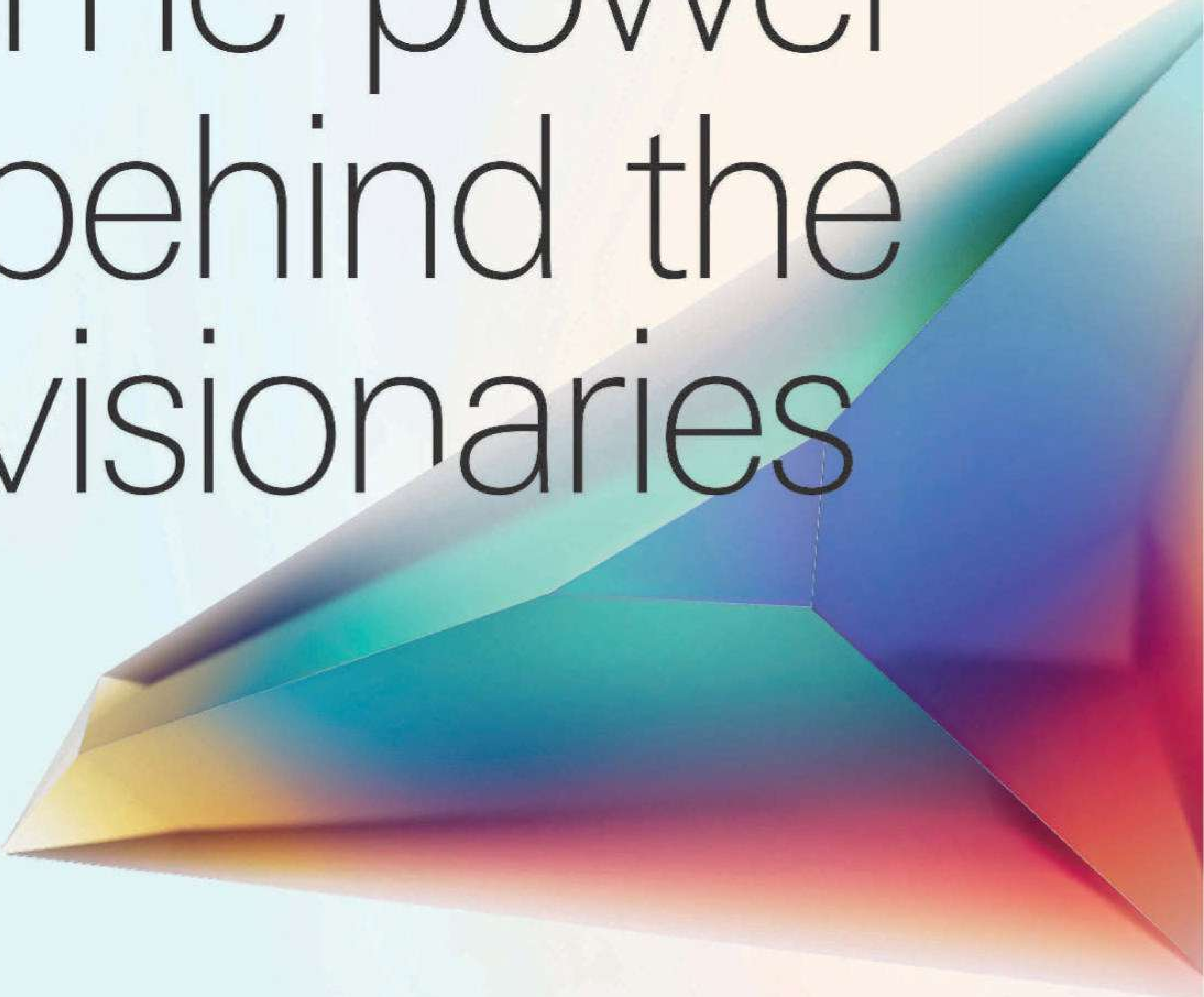

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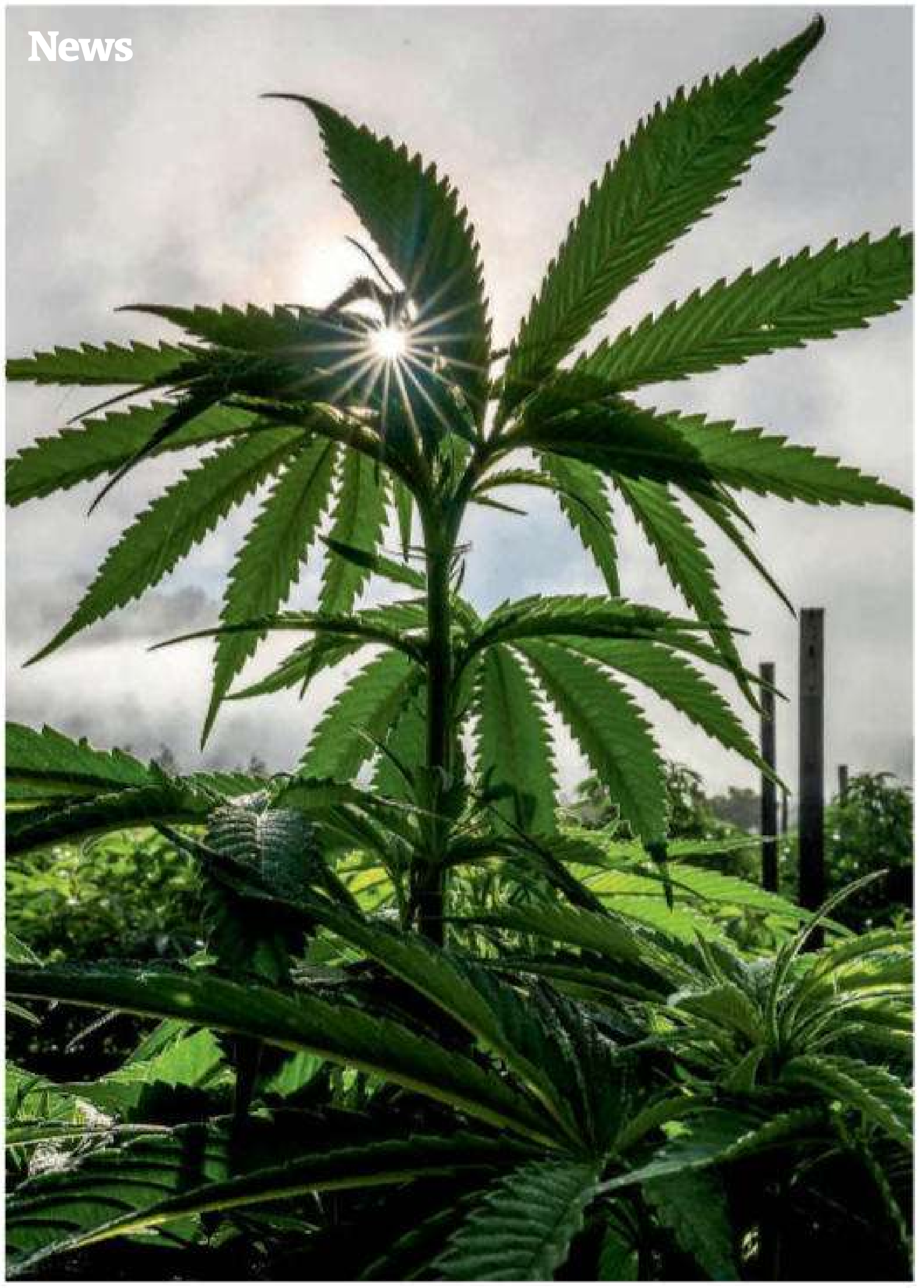

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Artificial intelligence

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Tour

Darwin's Galapagos

Sitting off the coast of Ecuador, this archipelago is a bucket list destination for wildlife buffs. Travel on a spacious and stylish yacht, accompanied by conservation advocate Jo Ruxton, as you immerse yourself amid the islands that served as inspiration for Charles Darwin's theory of evolution. This eight-day tour starts on 26 August 2024 and costs £6999.

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Podcast

Weekly

In this episode, the team discuss NASA's asteroid-studying Lucy mission, which flew past its first space rock en route to the Trojan asteroids of Jupiter. They also tell you how to identify where a starfish's head is – something that has been puzzling biologists since the 19th century. Hear what has been happening at the UK's AI Safety Summit. Plus, the team reveal what a flatworm's ability to regenerate has to do with sex.

newscientist.com/nspod

HENRY NICHOLLS/AFP VIA GETTY IMAGES

Octo-activist Greenpeace took its giant inflatable to Westminister

NASA/BILL INGALLS

NASA fly-by The Lucy mission is set for Jupiter's Trojan asteroids

Video

Protecting our oceans

Greenpeace took a 7-metre-high inflatable octopus to the Houses of Parliament in London to call on the UK government to ratify the High Seas Treaty, which would establish marine protected areas at a global level. Recently, UK ministers approved new North Sea oil and gas licences, which activists say pose a threat to marine biodiversity via oil spills and climate change.

youtube.com/newscientist

Newsletter

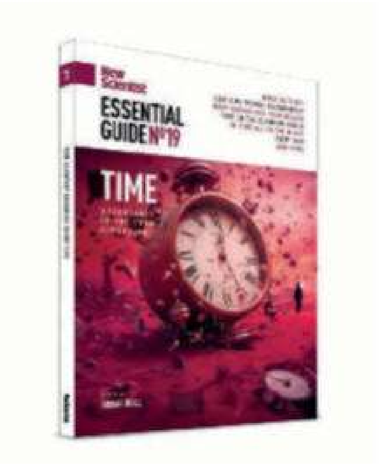
Health Check

The growing sleep tech industry keeps detailed data on your sleep patterns to help you get a good night's rest. Poor slumber has been linked to brain shrinkage, but Clare Wilson finds that obsessing over the number of hours you sleep may actually be counterproductive to your health and well-being.

newscientist.com/health-check

Newsletter

> "It's especially concerning that some people take sleeping pills to hit the 7-hour sleep goal"



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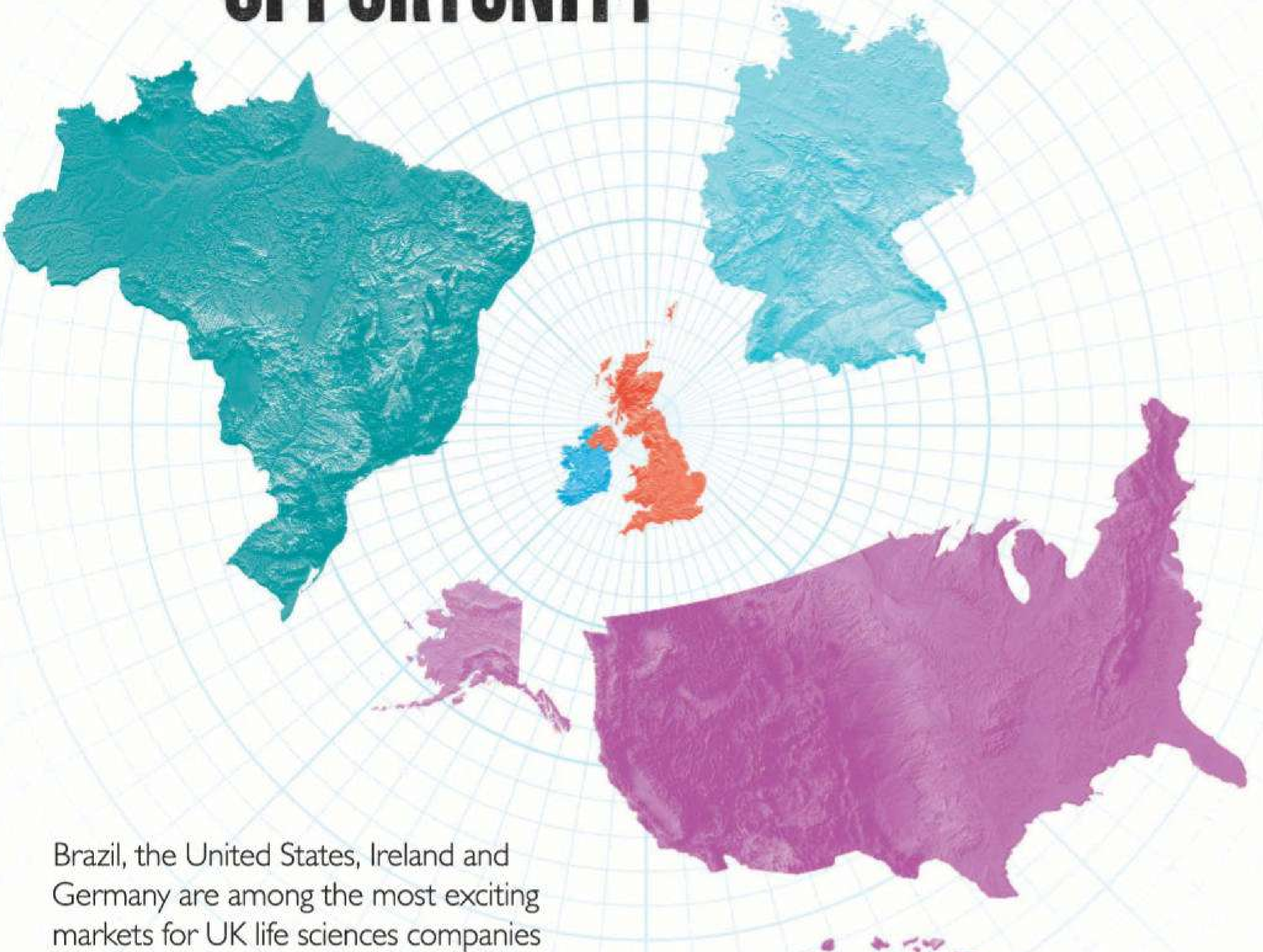

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Exploding the big bang

Our evolving understanding of the early universe leaves open intriguing possibilities

THESE days, cosmologists think of the big bang not as a single moment, but a longer period in which the nascent cosmos, then a ludicrously hot and dense soup, underwent a series of transformations before the universe we see today eventually emerged through a slower process of cooling and expansion.

But our understanding of this "hot big bang" remains sketchy at best. That means cosmologists have some freedom to generate new ideas about what really happened in the very early universe.

One intriguing possibility is that dark matter, the mysterious stuff thought to hold galaxies together, was formed in a separate event to normal matter. This "second big bang" might initially appear far-fetched. But as we explore on page 32, there are good reasons to consider it.

First, our failure to identify what dark matter is, despite decades of attempts to detect it, suggests we might need to rethink its origins. The scenarios being explored for a subsequent genesis throw up several new and exotic kinds of dark matter particle, including extremely massive ones called "darkzillas" that would have evaded our detectors.

> **"Scenarios being explored for a second big bang throw up new and exotic dark matter particles"**

Second, the idea of an alternative moment of creation for dark matter is in line with the realisation among cosmologists that the early universe was characterised by a series of phase transitions – moments in which a physical system undergoes a profound transformation.

But most importantly, perhaps, we may finally have a way to test this and other proposals for phase transitions in the early universe. In July, the North American Nanohertz Observatory for Gravitational Waves announced the detection of a background gravitational wave signal that could be coming from the first few weeks of the universe's existence.

If this observation holds up, it will open a window on the formative moments of the universe for the first time. Whether or not we see evidence of a dark matter big bang, we can expect a new understanding of how the cosmos we see came to be. ▮

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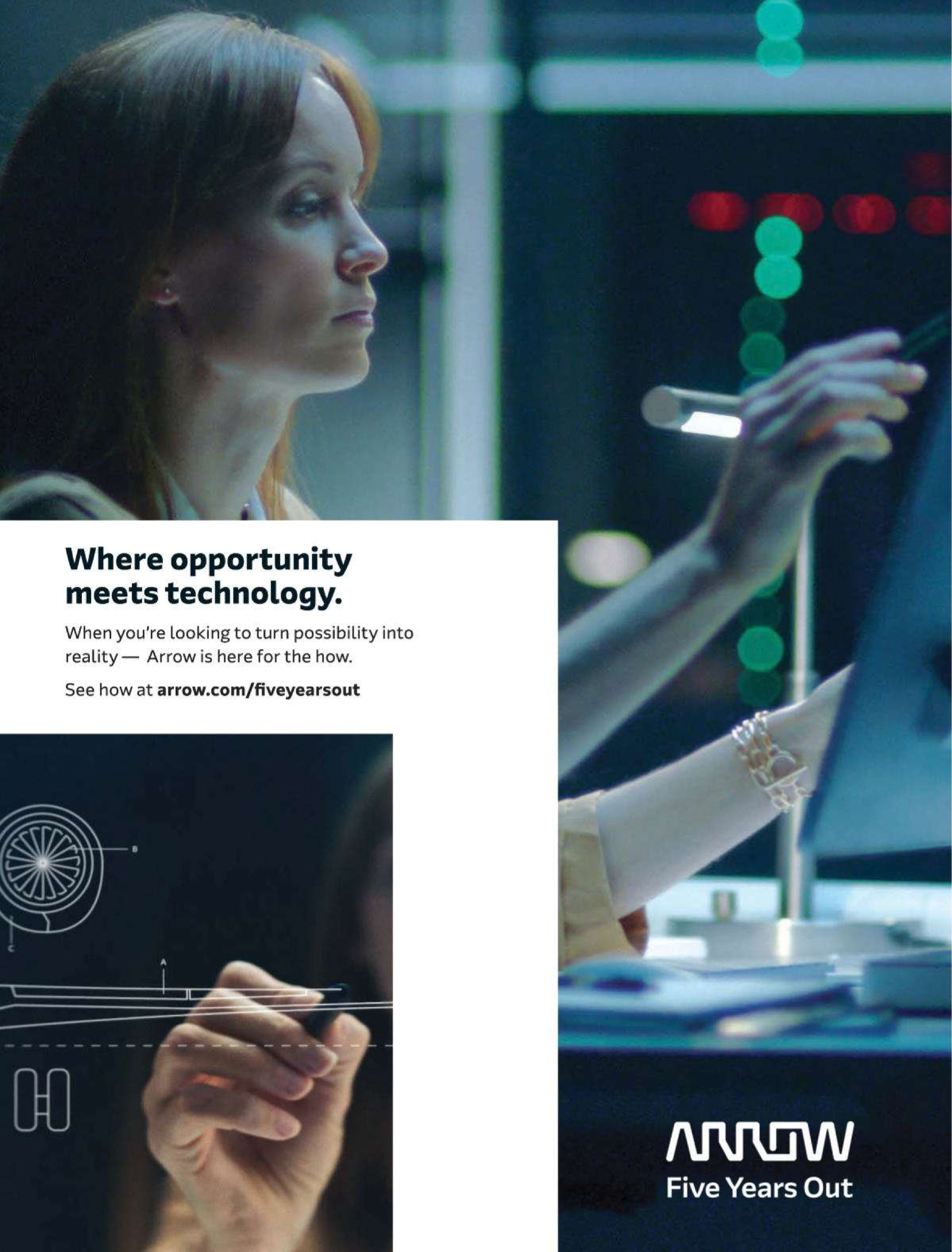

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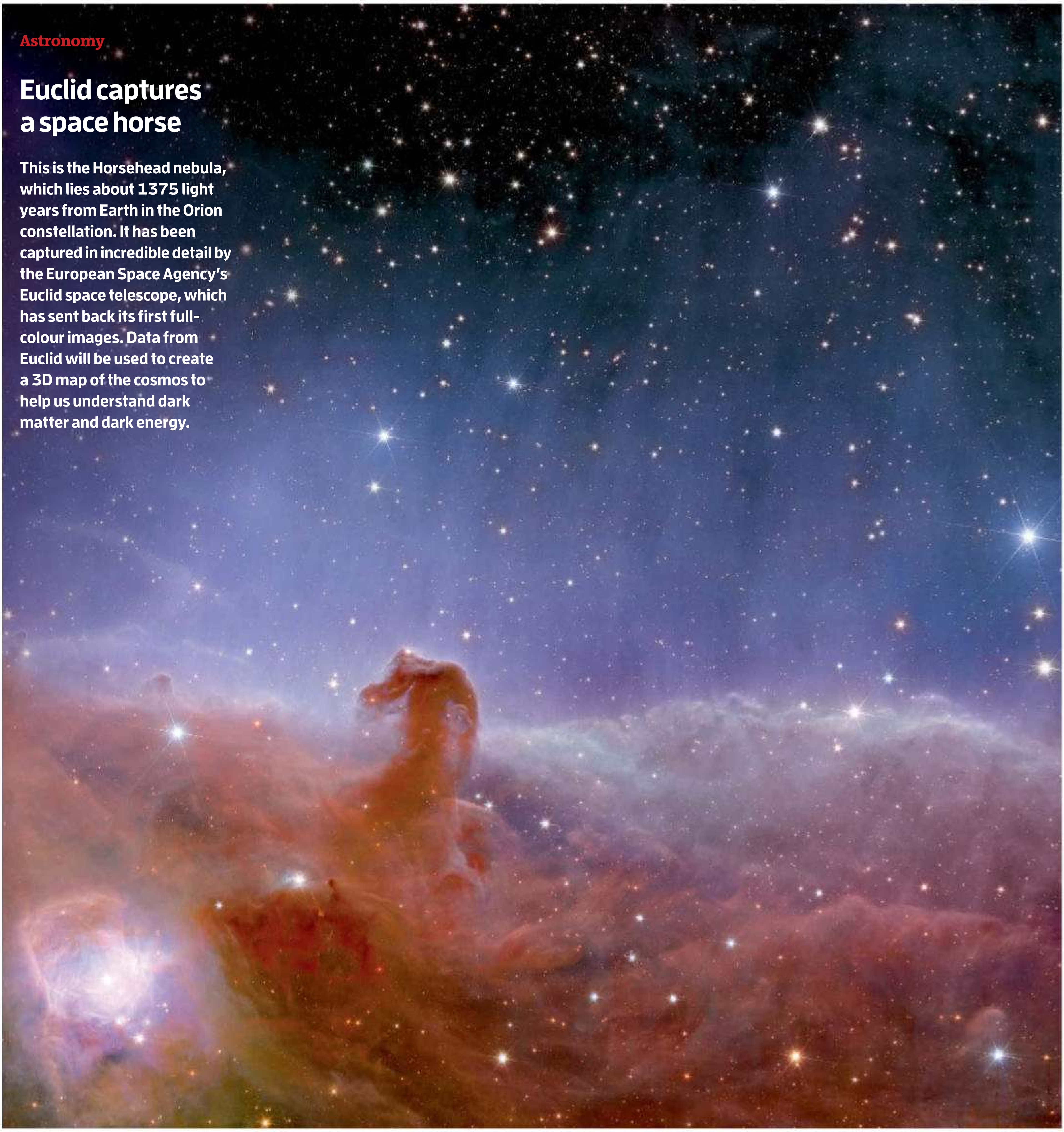

Astronomy

Euclid captures a space horse

This is the Horsehead nebula, which lies about 1375 light years from Earth in the Orion constellation. It has been captured in incredible detail by the European Space Agency's Euclid space telescope, which has sent back its first full-colour images. Data from Euclid will be used to create a 3D map of the cosmos to help us understand dark matter and dark energy.

ESA/EUCLID/EUCLID CONSORTIUM/NASA; J-C. CUILLANDRE (CEA PARIS-SACLAY), G. ANSELMI; CC BY-SA 3.0 IGO

Health

DNA vaccines on the horizon

Vaccines that contain DNA would be easier to store than mRNA alternatives and should be as effective as conventional vaccines that contain live viruses, says **Michael Le Page**

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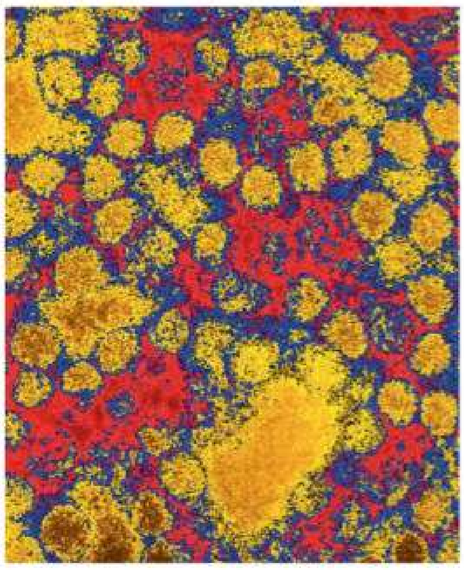


CDC/SCIENCE PHOTO LIBRARY

A candidate DNA vaccine may work against the yellow fever virus (above)

THE first human trials of DNA vaccines designed to produce live viruses in people's bodies could start next year. A company called Medigen has told *New Scientist* it is seeking approval for such trials.

The aim is to combine the potential advantages of DNA vaccines, including rapid manufacturing and easy storage, with the greater efficacy of vaccines that consist of live weakened viruses.

"So instead of giving live virus, we would give a piece of DNA and the body will make the vaccine," says Peter Pushko at Medigen in Frederick, Maryland.

Medigen has tested two potential vaccines of this kind in mice so far, one for chikungunya and one for yellow fever. The DNA vaccines protected the animals when they were later exposed to infection-causing viruses.

The company hopes trials in people will begin next year. "We are in discussion with the FDA [US Food and Drug Administration]," says Pushko. "As soon as we get the FDA approval, we can start testing in a phase I clinical trial."

> **"I anticipate they would have the production and storage ease of DNA, but the potency of a live virus"**

All early vaccines consisted of live viruses that caused milder symptoms than the conditions they were intended to prevent. Many vaccines today still consist of live weakened viruses, including the chickenpox and nasal flu vaccines.

The main advantage of live vaccines is that they typically produce strong and long-lasting protection after a single dose. The disadvantage is that in people with weakened immune systems, there is a risk of dangerous infections. It is also possible for weakened viruses to revert to the dangerous form, which happens with the live polio vaccine, albeit rarely.

Because of the safety issues, many modern vaccines consist of "dead" viruses that can't replicate or of viral proteins rather than an entire virus, such as the human papillomavirus and hepatitis B vaccines. However, these vaccines typically require repeated doses to produce a strong enough response.

With any vaccine that consists of entire viruses or viral proteins, manufacturing requires highly trained personnel and specialised facilities tailored to each vaccine. This means that ramping up production in the event of a pandemic is difficult, hence the interest in RNA and DNA vaccines.

DNA is found mainly in the nucleus of cells and stores the recipes for making proteins. Temporary copies of DNA recipes are made from RNA, and they carry the recipes from the nucleus to protein-making factories in the main cell body. These copies are called messenger RNAs or mRNAs.

The idea with both mRNA and DNA vaccines is to get our cells to do the hard part of manufacturing the viruses or viral proteins. RNA and DNA are relatively cheap and easy to produce, and the same manufacturing processes can be used to make different vaccines.

One potential advantage of DNA vaccines over mRNA ones is that the molecule is more stable. DNA vaccines can be kept in a fridge or even at room temperature, rather than needing to be kept frozen like most mRNA vaccines, says Pushko.

Special delivery

The problem is how to deliver the DNA. Whereas an mRNA vaccine only needs to get past the cell membrane, a DNA vaccine has to get into the nucleus of the cell. This requires special methods such as injection via microneedles, and many candidate DNA vaccines coding for viral proteins have failed to produce a strong enough immune response in trials.

No DNA vaccine has received full approval, though in 2021, India granted emergency authorisation to a covid-19 DNA vaccine that codes for two viral proteins.

DNA vaccines coding for live viruses help solve the delivery problem because once a few viruses are made, they start replicating themselves, says Pushko. So people get an effective dose even if relatively few DNA molecules reach the nuclei of cells.

To make it extremely unlikely that the live viruses encoded by the DNA vaccines will mutate back to the wild form, Medigen has also deleted some viral genes and rearranged others, says Pushko. It is also developing similar vaccines for other emerging infections of concern, including Lassa fever.

"I like the idea of this," says Anna Blakney at the University of British Columbia in Canada. "I anticipate it would have the production, stability and storage ease of [DNA], but the potency of a live attenuated virus. The main concern is the safety of a live attenuated virus, especially in an immunocompromised patient."

In the event of another pandemic, quickly producing a vaccine that gives protection after one dose could save many lives, says Pushko. ▮

Environment

Twin climate anomalies may trigger heat and drought in 2024

James Dinneen

THE unusual combination of a strong El Niño in the Pacific Ocean and a strong shift in temperatures across the Indian Ocean could intensify heat and drought in Australia and South-East Asia, and lead to flooding in East Africa.

In May, the Pacific Ocean saw the emergence of a warm El Niño climate pattern after three years of colder La Niña conditions. The shift contributed to the unprecedented heat seen this year, although the El Niño isn't expected to reach its peak strength for several months. Forecasts anticipating the potential for a historically strong event have raised alarm about impacts around the world in 2024. "There's a lot of factors conspiring to make it a strong event," says Pedro DiNezio at the University of Colorado Boulder.

One of those factors is a shift to cold temperatures in the eastern Indian Ocean and warm temperatures in the west. This pattern is the positive phase of a cycle called the Indian Ocean Dipole (IOD). "It's kind of like El Niño's little brother," says Kaustubh Thirumalai at the University of Arizona.

Similar to an El Niño in the Pacific, a positive IOD sees trade winds push warm water to the western Indian Ocean while cold water wells up in the east, with wide-ranging impacts on the region's climate.

In early September, the Australian Bureau of Meteorology declared that a positive IOD was under way. It is now forecast to continue at least until the end of the year. "This year is incredibly strong," says DiNezio.

It isn't unusual for an El Niño and a positive IOD to co-occur, about a third of positive IOD events on record are accompanied by an El Niño, says Caroline Ummenhofer at Woods Hole Oceanographic Institution in Massachusetts. Researchers also debate the extent to which the IOD is driven by the El Niño cycle and vice versa.

"If the two events co-occur, it means Australia is really in for very dry and very warm temperatures"

But the combination of a strong El Niño and a strong positive IOD is rare, says Hamza Varikoden at the Indian Institute of Tropical Meteorology. It hasn't been seen since the strong El Niño of 1997 to 1998, in which the IOD was first discovered. That period cost the global economy trillions of dollars.

Both strong events at once could reinforce or cancel out each other's influence on the global climate in complex ways. "It might be good news [in one place]," says Thirumalai. "It might be bad news somewhere else."

Generally, both a positive IOD and El Niño are associated with hotter, drier conditions in South-East Asia and much of Australia. "If the two events co-occur, it means Australia is really in for very dry and very warm temperatures," says Ummenhofer. There could also be wildfires in Indonesia and heatwaves across South-East Asia, says Thirumalai.

Both patterns are also associated with rain in East Africa, which could lead to more extreme flooding even as the region recovers from several years of severe drought.

Conversely, if it lasts far into 2024, the positive IOD could reduce the negative impact of El Niño on the Indian monsoon.

Climate change adds further uncertainty to how this event might compare with the 1997-98 period. "A lot of the associated influences are now happening on a very much warmer planet," says Ummenhofer. "That means any associated rainfall and drought have the potential to become more extreme." ▮

Archaeology

Man survived surgery on his skull 2700 years ago

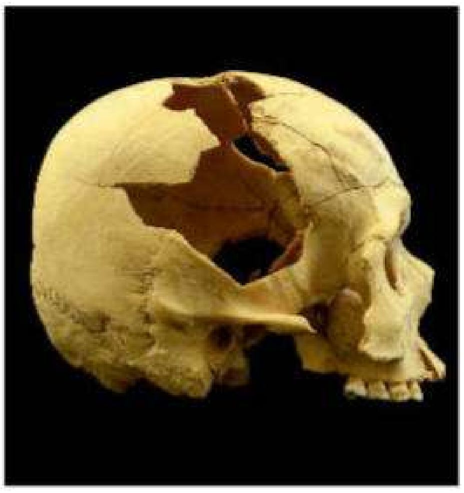
A MAN who lived in what is now China 2700 years ago had a hole cut in his skull to treat a head injury and survived. This suggests that shamanic doctors in that era could do advanced brain surgery.

The Yanghai cemetery in Xinjiang, China, contains the graves of a clan that practised shamanism, generally defined as a belief system that uses trance to communicate with the supernatural. Qian Wang at Texas A&M University and his colleagues used CT scans to analyse a skull found there from a man aged between 30 and 35 years who lived sometime around 750 to 800 BC.

This person had experienced a blunt-force injury causing an epidural haematoma, which is when blood accumulates under the skull. The condition puts pressure on the brain and can be life-threatening. To relieve the haematoma, someone removed part of the skull in a similar way to how this condition would be treated today. In modern surgery, this is called a craniotomy.

Signs of healing within the walls of the fracture lines indicate the man lived for at least eight weeks after the procedure (*Archaeological and Anthropological Sciences*, doi.org/k37d).

"In order to successfully remove the haematoma, the doctor was able to design a bone flap according to the injury by using the fracture lines," says Wang. He and his colleagues believe this is the most advanced ancient craniotomy ever found in the Xinjiang region and in the wider Eurasian steppe.


QIAN WANG

This ancient skull shows signs of healing after surgery to treat an injury beneath the bone

Wang thinks it likely that head surgeries were commonly performed by shamans in what is now China during the Bronze and Iron ages. There is no direct evidence that the procedure was done by a shaman doctor, but other discoveries back up the idea, says Wang. One individual in the Yanghai cemetery was identified as a shaman based on a bronze knife and pointed tool, called an awl, hanging from his waist. And cannabis has been found in the cemetery, which may have been used as an anaesthetic. ▮

Soumya Sagar

Neurology

Spine stimulator for Parkinson's

A man with Parkinson's disease who fell up to six times a day can now walk without falling

Jason Arunn Murugesu

A MAN with Parkinson's disease has experienced a substantial improvement in his ability to walk after being fitted with a device that electrically stimulates his spinal cord. The findings, although based on one person, suggest this could be used to treat movement deficits in people with the condition.

Around 90 per cent of people with Parkinson's experience some kind of movement difficulty, says Grégoire Courtine at the Swiss Federal Institute of Technology in Lausanne (EPFL). Treatments include drugs that target parts of the brain affected by a loss of the chemical dopamine, which regulates movement, as well as deep-brain stimulation, which focuses on these brain areas and changes some of the abnormal electrical signals that cause symptoms.

However, many people with Parkinson's disease don't respond to these treatments, particularly if their condition is advanced, says Courtine. He and his colleagues wanted to find out whether directly stimulating the spinal cord in a person with severe Parkinson's disease could help.

They focused on epidural electrical stimulation (EES), which can modulate the activity of neurons behind locomotor movements. Previous studies showed that the technique can restore walking in people with paralysis after a spinal cord injury.

The team devised a form of EES that specifically targets neurons in the spine that are activated when legs walk, which showed promise in non-human primates with Parkinson's-like symptoms. To test it in a person, the researchers recruited a 62-year-old man called Marc, who has experienced Parkinson's symptoms for around 30 years. These included severe motor issues, particularly gait freezing – sudden and temporary episodes of an inability to move.

Marc no longer has to rely on a cane to support him when out and about

CHUV 2022/WEBER GILLES

For the method to be effective, the researchers first had to map the neurons in Marc's spine. This helped to guide the implantation of stimulators so they would only target his legs' neurons.

They then placed sensors on Marc's legs and shoes to monitor the electrical activity of the neurons that activate the muscles in these limbs and his feet. When these sensors detected this electrical activity, they activated the stimulators (*Nature Medicine*, doi.org/k38c).

After three months of rehabilitative training using the stimulators, Marc more or less stopped experiencing gait freezing, says Courtine. Marc says that passing through narrow paths or turning as he walked had previously caused gait freezing, which led to him falling five or six times a day. Marc has now been using the stimulator for two years and says he hardly falls at all any more, allowing him to walk several kilometres at a time.

The stimulation is personalised to Marc, who found it particularly difficult to move one leg, says Courtine. Nevertheless, the team thinks a similar technique could help many people.

"In response to the precise stimulation of the lumbar spinal cord, [we have] observed for the first time the remarkable improvement of gait deficits due to Parkinson's disease," says team member Jocelyne Bloch, also at EPFL. "I really believe that these results open realistic perspectives to develop treatments that alleviate gait deficits due to Parkinson's."

The researchers hope to test this method in more people, says Bloch. There are at least five more years of development before the treatment will reach people outside a trial, says Courtine. ▮

Astronomy

The sun is slightly smaller than we thought it was

OUR sun is fractionally smaller than it seems, which could change our understanding of its internal structure and behaviour.

Historically, astronomers have estimated the sun's size by measuring the part that emits light, called the photosphere. This is done during a solar eclipse.

A different estimate of the sun's radius can be found by measuring sound waves travelling through it. In the 1990s, astronomers did this using sound waves near the sun's surface, called f-waves.

By using a model of the sun's interior and the circulation of its plasma – a hot gas stripped of electrons – beneath the surface, these researchers found the photospheric radius to be slightly smaller than the directly measured photosphere, which suggested that our understanding of the sun's interior was incomplete.

Now, Douglas Gough at the University of Cambridge and Masao Takata at the University of Tokyo have calculated the solar radius using a different kind of sound wave, called p-waves, which are created by the movement of material inside the sun and can pass easily through its core. Their calculation also gives a smaller result than the measured photosphere, by a few hundredths of a per cent (arXiv, doi.org/k37r).

That difference is big enough to alter what properties we infer the sun has based on the vibrations picked up from its seismology, says Gough. "Seismological inferences are saying things that relate to the nuclear reactions, the chemical composition and the basic structure of the sun," he says.

"There's the potential to reach misleading conclusions about the sun's internal structure"

Gough and Takata say a different radius would also mean different depths for the layers of the sun's plasma.

"There's the potential to reach misleading conclusions about the subtle elements of the sun's internal structure" if we have the wrong radius, says William Chaplin at the University of Birmingham, UK. ▮

Alex Wilkins

Health

Eight healthy habits could slow your rate of ageing

Chen Ly

FOLLOWING eight healthy behaviours could cut years off your biological age, which may help to keep you in good health for longer.

The Life's Essential 8 checklist was created by the American Heart Association (AHA) to help people improve cardiovascular health. Its recommendations include getting at least 150 minutes of moderate or 75 minutes of vigorous physical activity per week, eating a balanced diet full of vegetables, nuts and lean protein, and not smoking.

The remaining recommendations are to get between 7 and 9 hours of sleep a night, maintain a healthy weight and keep cholesterol, blood sugar and blood pressure in check.

Now, Nour Makarem at Columbia University in New York and her colleagues have found that adhering to this checklist doesn't only boost heart health, but could also decelerate the biological ageing process. They will present the work at an AHA meeting in Philadelphia on 12 November.

The researchers assessed how closely more than 6500 participants of the National Health and Nutrition Examination Survey followed the checklist. This was based on people self-reporting their adherence to its recommendations, while their weight, cholesterol, blood sugar and blood pressure were all measured. The team also calculated people's phenotypic age, an indication of biological age determined by measuring levels of chemicals in the body that are involved in metabolism, inflammation and organ function, such as glucose and creatinine.

Those who reported the best adherence to the checklist had a biological age that was, on average, six years younger than their chronological age. Those with the worst adherence had an average biological age four years older than their chronological age. ▮

Analysis Artificial intelligence

What did the UK's AI Safety Summit achieve? With a lack of concrete decisions, the much-publicised meeting could probably just have been an email, says **Matthew Sparkes**

IN THE weeks leading up to the UK's AI Safety Summit, held on 1 and 2 November, prime minister Rishi Sunak repeatedly stressed the potential risks that artificial intelligence could pose to society. Then, on the second morning of the event, he told reporters that people must avoid "alarmist" claims – just before warning that AI could be as dangerous as nuclear war. It is safe to say there were mixed messages.

But the summit at Bletchley Park was, of course, intended to disperse this fog of confusion: to examine the risks of AI, allow politicians to talk with business leaders and technology experts, and, ultimately, plan for a future that avoids disastrous pitfalls. Was all this achieved?

The main takeaway of the event was the new Bletchley Declaration, signed by 28 nations, including China and the US, along with the European Union. Getting any sort of international consensus in these tense political times is a success, but the document does little more than acknowledge that there are risks from AI and pledge to explore them. The only concrete action promised in the wording is to hold more summits in the future. Perhaps, instead of this meeting, there could have been a ChatGPT-generated email, saving the carbon emissions of jetting all the participants in.

"Having another meeting doesn't seem ambitious enough given the rapid development of AI"

Carissa Véliz at the University of Oxford, a leading AI ethicist who wasn't invited to the meeting, is unimpressed by a summit that promises more summits. "We've already been slow to regulate AI and reach international agreements on it. Having another meeting in future doesn't seem ambitious enough given the high stakes and the rapid development and implementation of AI," she told *New Scientist*.

It is worth remembering that it is only a year since OpenAI launched ChatGPT and just eight months since the AI chatbot saw an upgrade to the more powerful GPT-4 model. Who knows what version number we will be on by the time leaders meet again to discuss AI?

Gary Marcus at the Center for the Advancement of Trustworthy AI says the Bletchley Declaration is welcome, but doesn't go far enough and doesn't represent a broad enough cross-section of society. "We urgently need to move past position statements – there have been a lot of those in recent months – and into concrete proposals about what to do next."

Marcus believes that an executive order on AI by US president Joe Biden, released the same week as the Bletchley summit, comes far closer to laying out real policy. It orders a wide array of US government agencies to develop guidelines for testing and using AI systems. The EU, too, is working on AI legislation.

There seems to be no lack of will to regulate AI, but as yet an almost total absence of detail, beyond a deal announced at the summit that will see tech firms including Google DeepMind and OpenAI share information with a new UK AI Safety Institute.

Clark Barrett at Stanford University in California says that much of the Bletchley Declaration is "predictably vague and thus runs the risk of being words with no actions attached". But its talk of "building a shared scientific and evidence-based understanding of these risks" is a sensible way forward, if followed through, he says.

The reality is that technology – as has always been the case – is outpacing legislation. And if the world's law-makers at least got up to speed on the latest developments in AI at Bletchley Park last week, it is hard to imagine they won't need a refresher course by the time they meet again, with the face of AI having transformed once more. ▮

UK prime minister Rishi Sunak and other world leaders at the AI summit

SOEREN STACHE/DPA/ALAMY

Health

Why ADHD medicines are hard to get

A global shortage of medications for ADHD means many are going without. **Clare Wilson** explains what is causing this and what to do if you are affected

AROUND the world, many countries are experiencing shortages of medications to treat the adverse symptoms of attention deficit hyperactivity disorder (ADHD). The condition tends to affect people's concentration and make them restless and impulsive. Medicines can help people with ADHD focus and feel calmer, but supply hasn't been able to keep up with demand. Here is what you need to know.

Which ADHD medicines are affected?

There are several kinds of drugs used to treat adverse symptoms of ADHD, most of which are in short supply. These include three of the most commonly used drugs – stimulants called amphetamine mixed salts, methylphenidate and lisdexamfetamine – with manufacturing delays reported by two firms, Teva and Takeda.

> "Exercise may ease ADHD symptoms by tapping right into the same mechanisms as medication"

These shortages seem to have had knock-on effects on the supply of less commonly used ADHD medicines. The disruptions are occurring in many countries around the world, including the US and Australia. Some, such as the UK, now have export bans in place.

Is this because more people are being diagnosed with ADHD?

Yes – rising global demand has contributed to the problem, the UK government has said. In the UK, for instance, diagnoses among men rose nearly 20-fold between 2000 and 2018. In the US, the biggest contributor to the rising demand for ADHD medicines was among adults, aged 22 to 44, with prescriptions for the most commonly used drug rising by about 50 per cent in this group between 2018 and 2022.

CAROLYN VAN HOUTEN/THE WASHINGTON POST VIA GETTY IMAGES

A rise in ADHD diagnoses means that medication supplies are low

In September, doctors in the UK were told not to start writing prescriptions for people newly diagnosed with ADHD until the supply problems have eased.

How long will this shortage last?

US supplies of lisdexamfetamine should improve due to generic manufacturing that began in August. The UK government has said that the overall ADHD drug shortage there may continue until December.

What can you do if you are running low on such medication?

Users of these treatments are being advised to ring up different pharmacies, as supplies can vary in different stores. People can also ask their doctor to prescribe a different brand of medication, as their availability varies and they may be able to switch between drugs.

With some ADHD treatments – although not all of them – there may also be ways to reduce the dose, for instance by taking half the amount per day. But if the dose had been set at just the right level to optimise mental well-being, it would then be too low, says Ulrich Müller-Sedgwick at the UK's Royal College of Psychiatrists. "You would have more symptoms."

People shouldn't change the dosing regimens of their medication without consulting a doctor first.

What happens if you run out?

Some people taking stimulant medicines may already be used to stopping and starting their treatment, as the drugs are short-acting and so some people only take them on days when they are most needed, says Sally Cubbin at the Adult ADHD Clinic in Oxford, UK. For instance, children may stop taking the medicines in school holidays or adults may skip doses at the weekends.

20x

The increase in ADHD diagnoses in UK men from 2000 to 2018

50%

The rise in ADHD medicine demand in 22 to 44-year-olds in the US

The downside is that symptoms return on days when doses are missed. "Some people take them every day, because they feel that it isn't just about focusing on tasks, it might also be about emotional stability," says Cubbin. People may also focus better while driving, for instance, on days when they take ADHD medicines, she says.

The two kinds of non-stimulant medications used for ADHD shouldn't be stopped abruptly, says Müller-Sedgwick. One, called atomoxetine, has a similar mechanism to antidepressants, while another, guanfacine, can cause raised blood pressure if it isn't reduced slowly.

Can adverse ADHD symptoms be treated without medication?

For children, the first steps after diagnosis usually involve health professionals giving advice to parents and schools on behavioural strategies. This may include using consistent discipline with positive reinforcement.

Among adults, medication is usually the first approach, although there is some evidence that mindfulness courses can help with adverse symptoms.

Exercise may also help all ages, perhaps because it can raise levels of a signalling chemical called dopamine in the brain, which is also the effect of ADHD stimulant medicines. "It's possible that exercise is actually tapping right into the same mechanisms as medication," says Eleanor Dommett at King's College London. ■

Environment

Ocean heat could supply limitless clean energy to tropical islands

James Dinneen

A 140-year-old idea to exploit the temperature differences between layers of the ocean is gaining new interest as a way to provide clean power for people living on islands.

Called ocean thermal energy conversion (OTEC), the idea is to use surface water warmed by the sun to heat a fluid such as ammonia or water, which then spins a turbine as it evaporates, just like a power plant driven by steam. Cold water from deeper layers of the ocean would then be piped up to cool the fluid and repeat the cycle.

Theoretically, oceans could provide vast amounts of electricity like this. Researchers have estimated that there is enough ocean heat to supply 7000 gigawatts a year without affecting ocean circulation, enough to supply the world's electricity demand – if we can access it.

The idea was first proposed in 1881, but went largely unexplored until the 1970s oil crisis drove a search for new sources of energy. In the years since, demonstration projects have been built, but progress has been "disappointing", says Al Binger at SIDS DOCK, an organisation that promotes clean energy development in small island countries.

In recent years, a fresh urgency to transition away from fossil fuels has brought hints of an OTEC resurgence. "It's the most promising it's been in many decades," says Andrea Copping at the Pacific Northwest National Laboratory in Washington state.

For example, a small OTEC plant has been supplying energy to the grid in Hawaii since 2015, and another has been running in Okinawa, Japan, since 2016. Other projects have been tested, but Gérard Nihous at the University of Hawai'i at Mānoa says there is still a "psychological barrier" to investing in OTEC after past flops.

Now, UK-based company Global OTEC is hoping to demonstrate commercial viability. The firm has designed a 1.5-megawatt floating system, which is planned to supply power to the island nation of São Tomé and Príncipe by 2026. The company has been in talks with other interested island governments, such as Fiji's.

Tropical islands are good candidates for OTEC because of their high energy costs – diesel generators are common there – and the presence of deep cold water not far from shore, says James VanZwieten at Florida Atlantic University. Islands also have less space for other types of renewables.

"[With OTEC] we keep our ecosystems, we keep our land and we keep our water resources," says Binger, who is working with Global OTEC to promote this form of energy.

A barrier for past projects was the cost of installing kilometres of large pipes to reach deep water. Global OTEC aims to avoid that by extending a shorter pipe from a platform floating in deep water 10 kilometres offshore, then transmitting electricity back via a cable, making use of advances made in offshore wind technology.

"OTEC will be part of providing an equitable transition so these places aren't depending on diesel imports from the richest petrol states in the world," says Dan Grech, Global OTEC's CEO. ▮

Artist's impression of Global OTEC's power system (below), which is planned for São Tomé in West Africa (right)

GLOBAL OTEC

SHUTTERSTOCK/XINOVAP

Animal behaviour

Rats squeak with joy when they are with another rat

RATS seem to emit ultrasonic squeaks of happiness when they are in the company of another rat.

People can hear the "alarm" squeaks that rats sometimes make when they are distressed, but most rodents' calls have frequencies well beyond the human hearing range, which in adults usually maxes out at around 17 kilohertz.

Scientists have previously discovered that rats make very high-pitched, choppy squeaks (at about 50 kHz) when they are happy and produce lower-pitched, longer calls (at about 22 kHz) when they are discontented.

Microphones placed in cages have previously picked up high-pitched happy squeaks in groups of rats, but such set-ups don't accurately distinguish which rats are squeaking in different circumstances. To overcome this, Shai Netser at the University of Haifa in Israel and his colleagues invented a miniature microphone that they could attach to the noses of 13 rats via a surgically implanted tube. They then placed the rats in cages with a second rat, either so that they were free to interact or separated by a wire mesh, and recorded the noises they made.

As expected, the rats made more high-pitched happy squeaks when in physical contact with another rat, says Netser. But to their surprise, the researchers found the rats didn't make those squeaks in reaction to anything the other animal did. Instead, they seemed to come at random, as if the rats were just expressing positive emotions (*Cell Reports Methods*, DOI: 10.1016/j.crmeth.2023.100638).

"The squeaks seemed to come at random, as if the rats were just expressing positive emotions"

The mini-microphones also discovered a new rat sound: a very soft squeak that is within human hearing range, at around 6 kHz. "But they just don't produce it when they are near us," says Netser. "They only produce it near each other." The meaning of this sound is unclear.

Future studies with the mini-microphones may help us research social behaviours among rats. ▮

Christa Lesté-Lasserre

Physics

Breaking causality improves quantum battery charging

Karmela Padavic-Callaghan

QUANTUM batteries could charge more efficiently by skirting the conventional rules of causality.

Yuanbo Chen at the University of Tokyo in Japan and his colleagues have analysed whether a counterintuitive quantum phenomenon could play a role in powering quantum batteries – energy storage devices that could harness quantum effects.

In the classical world, causality goes in one direction: if event A causes event B, then B didn't also cause A. But at the quantum scale, Chen says it can be impossible to tell which way such causality goes. This is called indefinite causal order. Both directions of causality can be put in a so-called quantum superposition where both and neither are simultaneously true.

Chen and his colleagues applied this idea to two chargers powering a quantum battery. They calculated how much energy the battery would gain and how efficiently it would charge for three protocols: one where the chargers were connected sequentially, one where the chargers simultaneously powered the battery and one where it was impossible to tell which charger was at work because these two causalities were in a superposition.

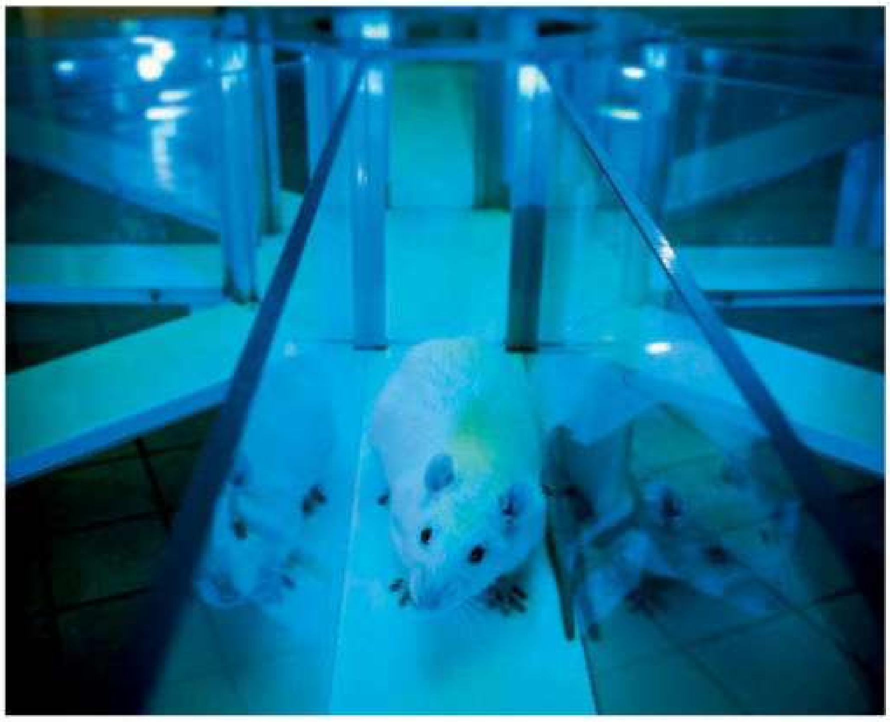
This last approach gave the battery the most energy in the most efficient way even when the connection between the chargers and the batteries was relatively weak, meaning it could work well even for suboptimal chargers. The work will be published in *Physical Review Letters*.

Chen and his colleagues performed a proof-of-principle experiment with quantum light that showed that this indefinite causality protocol could be implemented with a device called a quantum switch. However, they haven't directly tested charging a fully fledged quantum battery yet. ▮

Mind

Rats can mentally recreate places they have visited before

Jason Arunn Murugesu



PATRICE LATRON/GETTY IMAGES

Rats visually recalled where they had been before in a VR tunnel

JUST like someone may look back on a treasured holiday, wishing they were still there, rats can imagine being in places they have visited before.

A region of the brain called the hippocampus, which plays a big role in memory, is very consistent across mammals, which led scientists to suspect that non-human animals are similarly capable of imagining places they have been to before.

To investigate, Albert Lee at the Beth Israel Deaconess Medical Center in Boston, and his colleagues devised a 360-degree virtual reality (VR) arena. They had three rats walk on a treadmill within this, but the VR made it look to the animal like it was moving through a space resembling a dark tunnel.

The rats were trained to find certain shapes within the VR for a reward of sugary water. While they looked for these, electrical signals were recorded from their hippocampus. The researchers used this data to produce a brain-machine interface that reverse engineered the signals produced by the rats into images that were then displayed in the VR arena. They also wondered if a rat imagining a location within the VR, which involves the activation of hippocampal cells, would cause it to appear in the arena.

In a second experiment, the researchers tested this idea by getting the rats to do two tasks.

> **"To my mind, this shows not only that rats are capable of mental time travel, but that they are conscious"**

These both involved the rats being placed on a treadmill, but, unlike before, moving didn't affect what they saw.

In the first task, the rats had to imagine navigating to a particular shape they had already seen, for instance a circle, to receive sugary water. By envisaging locations in the VR that they had been through, the rats activated certain hippocampal cells, which was translated by the brain-machine interface into images in the VR.

The rats quickly learned that moving on the treadmill didn't get them closer to the shape, but imagining how they would reach it led to what they saw in the VR changing, bringing them closer to the circle, says Lee. "They grasp it really fast," says team member Chongxi Lai at the Howard Hughes Medical Institute in Maryland.

In the second task, the rats learned to move a shape in the VR to a specific location using their imagination. Unlike in the first task, the world around them didn't move, which caused the animals to move less themselves. "We wanted them to sit still and imagine, just like humans," says Lai. The rats did both tasks successfully (*Science*, doi.org/k3w8). "This is the first time it's been shown that animals can control this internal model of the world in their hippocampus," says Lee, who expects that the similarity of the hippocampus across mammals means they are all capable of such thoughts.

But how similar a rat's imagination is to a person's remains an open question, says Lee. The researchers plan to examine this in future studies.

"The study shows that rats can imagine doing things in a way very similar to us, without actually doing them," says Frank Sengpiel at Cardiff University, UK. "The rats were able to wilfully control the activity of the nerve cells in their hippocampus, very much like what we do when we imagine things. To my mind, this shows not only that rats are capable of mental time travel, but also that they are conscious." ▮

Space

Lucy discovers a double asteroid

NASA's spacecraft found a surprise second object as it passed asteroid Dinkinesh

Leah Crane

NASA's Lucy spacecraft flew past the small asteroid Dinkinesh on 1 November, and its observations revealed that Dinkinesh has an even smaller space rock orbiting it – the smallest main-belt asteroid ever observed up close.

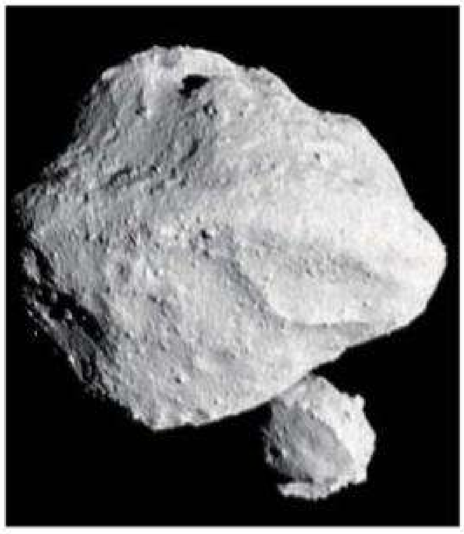
Lucy launched in October 2021, and since then it has been flying at about 19.4 kilometres per second towards the outer solar system. Its main targets for exploration are the Trojan asteroids, which share Jupiter's orbit around the sun. One clump of Trojans moves just ahead of Jupiter, while the other follows just behind it.

Dinkinesh isn't a Trojan – rather, it is in the main asteroid belt, between the orbits of Mars and Jupiter. That makes it a good pit stop on the way to the Trojans to make sure Lucy's scientific instruments will work properly for the other nine asteroids it will observe.

Finding Dinkinesh's smaller partner wasn't entirely a surprise. As Lucy approached Dinkinesh, the asteroid's brightness seemed to oscillate, which is often an indication of the presence of some sort of satellite. Dinkinesh is only about 790 metres across, though, so it was impossible to spot its satellite from Earth and even the spacecraft was still too far away to tell for sure until 1 November.

During the 1 November flyby, Lucy flew just 430 kilometres away from Dinkinesh at a speed of about 16,000 kilometres per hour, snapping pictures as it went by. The pictures were sent back to Earth and revealed a small asteroid in a binary with Dinkinesh, this one only about 220 metres across.

The asteroid Dinkinesh and its smaller orbiting partner



NASA/GODDARD/SWRI/JOHNS HOPKINS APL/NOAO

"We knew this was going to be the smallest main belt asteroid ever seen up close," said Keith Noll at NASA's Goddard Space Flight Center in Maryland in a statement. "The fact that it is two makes it even more exciting. In some ways these asteroids look similar to the near-Earth asteroid binary Didymos and Dimorphos that [NASA's Double Asteroid Redirection Test mission] saw, but there are some really interesting differences that we will be investigating."

The main goal of the instrument test was to ensure Lucy's tracking system, which keeps it pointed at its target as it hurtles by, was working. This system is important because of the asteroids' relatively small size and the spacecraft's extreme speed as it whips by.

"For the Trojans, we have a very good estimation of the orbit, but there is still an uncertainty of about 100 miles, and when you approach these targets you don't want to miss them," says Noemí Pinilla-Alonso at the University of Central Florida.

Other data from the encounter with Dinkinesh, such as basic measurements of its surface, is being sent back to Earth for the mission's scientists to dig into.

"The other asteroids of the same size that NASA has visited are near-Earth asteroids, so one thing that we want to see is whether the shape of this kind of object in the main belt is similar to the shape of objects that have been delivered to the inner solar system," says Pinilla-Alonso.

Now that Lucy is past Dinkinesh and its partner asteroid, its next target is the asteroid 52246 Donaldjohanson, which it will visit in 2025 before speeding onwards to Jupiter's Trojan asteroids.

The Trojans are probably crumbs left over from the formation of the solar system, so they could hold valuable insights as to how the planets formed and evolved over time. Lucy will reach the Trojans in 2027. ▮

Physics

Left-handed badminton players get an advantage

BADMINTON players who are left-handed could have a slight advantage thanks to the shape of the shuttlecock, a physicist has discovered.

Professional badminton players use feather shuttlecocks, which are usually made from about 16 overlapping feathers inserted in a cork base. This introduces an asymmetry that means a shuttlecock naturally spins anticlockwise as it flies, unlike a tennis ball, which will spin in either direction.

To study if this anticlockwise spin affects left and right-handed players differently, Eric Collet at the University of Rennes in France recorded and analysed videos of three left-handed and three right-handed people playing badminton. He found a key difference in the players' forehand slice shots, a common move where the racket brushes the shuttlecock to change its angle of travel.

For right-handers, playing this shot made the shuttlecock spin even faster anticlockwise. Meanwhile, left-handed players strike from the opposite side, which causes the shuttlecock to spin clockwise instead (arXiv, doi.org/k37v).

"The shuttlecock is rotating the opposite direction, then stops spinning and starts rotating around its natural rotation axis again," says Collet. This means the shuttlecock is slowed down rapidly by the air and falls faster, following a path that is about 15 degrees steeper than the same shot from a right-handed player. To reach it, the opposing player needs to travel further and stoop lower to defend the shot, giving left-handers an advantage, says Collet.

> **"People knew that left-handed players have a good slice. Now we know why"**

"People knew that left-handed players have a good slice," he says. "Now we know why."

There is no significant difference in the number of left and right-handed winners of professional badminton matches though. This implies right-handed players have adapted the left-handed slice shot or have advantages elsewhere. ▮

Chen Ly

Health

Mysterious cannabis syndrome

A growing number of marijuana users are experiencing prolonged vomiting, a condition that may be related to the increased use and potency of the drug, finds **Corryn Wetzel**

DOCTORS are reporting a rise in people coming into emergency rooms with stomach pain and unrelenting vomiting. They compulsively take hot showers. Anti-nausea medication offers little relief. The unexpected culprit is cannabis – overconsumption can lead to what is known as cannabinoid hyperemesis syndrome (CHS).

"Many patients with CHS have violent hurling when they arrive to the emergency department," says Sam Torbati at Cedars-Sinai Medical Center in Los Angeles. They often show up weak and dehydrated, and sometimes lose consciousness, he says.

> **"The illness led to a new word – 'scromiting' – to describe simultaneous screaming and vomiting"**

Cannabis is commonly associated with relieving nausea – so much so that chemotherapy patients are often prescribed medications containing THC, the psychoactive compound in the plant. But in humans and some other mammals, high doses of THC can have the opposite effect.

CHS is a relatively newly defined condition, first described in a handful of cases in Australia in the early 2000s. There is no blood test or scan to determine whether someone has the condition, so doctors instead look for a combination of symptoms including unrelenting nausea, bouts of vomiting and stomach pain. The intensity of this illness has led to the informal advent of a new word – "scromiting" – describing episodes where people are simultaneously vomiting and screaming in pain.

"The cause of this syndrome is unknown," says Linda Parker at the University of Guelph in Canada, but it seems to be limited to long-term and high-dose users – so people won't come down with this condition after a single toke.

CHS has a series of escalating phases, which can last days to years. A loss of appetite builds to the "hyperemetic phase", which includes persistent, painful vomiting. This is usually when people begin compulsively bathing in hot water, which may offer temporary relief by diverting blood flow from the abdomen to the skin or possibly by activating a part of the brain called the hypothalamus, which is involved in both temperature regulation and appetite, among other things.

A growing problem

Though still rare, the prevalence of CHS has soared in the past decade. For example, one study found that the rate of emergency room admissions for it in Ontario, Canada, increased 13-fold from January 2014 to June 2021.

CHS shows up unpredictably, which makes it even trickier to spot. Decades-long marijuana users can develop CHS late in life, while some young people are coming down with the condition after a few years of heavy smoking.

Mounting research suggests one reason for the increase in cases may be greater access to marijuana, from vapes to edibles. In Colorado, there was a 29 per cent increase in vomiting-related emergency room visits in the five years following legalisation of the drug for recreational use.

A similar pattern has played out in Alberta, Canada. After marijuana was legalised in the province in 2018, the rate of CHS-related emergency room visits went from 15 per 100,000 people, to 21 per 100,000. In 2020, it jumped to 32 visits per 100,000 people across all age groups. For those aged 16 to 24, the rate climbed to 600 per 100,000 individuals.

One reason that CHS is more common among young adults may be because they consume the most marijuana. Another factor may be potency. Cannabis available today contains more than 10 times as much THC, on average, as it did in the 1970s.

Doctors can manage some symptoms with medication and intravenous fluids, but the only "cure" is cutting out cannabis and waiting for symptoms to subside, which may take months.

Rewiring the brain

Some find temporary relief from creams containing capsaicin, the active ingredient in chilli peppers, applied to the arms and belly. Experts think this warming sensation, similar to the effect of taking a hot shower, activates a receptor in the stomach that can calm nausea and vomiting.

Experts don't know the exact mechanisms behind why cannabis can trigger this illness, but they agree that THC is to blame. The compound binds to receptors in the endocannabinoid system, which regulates sleep, appetite, mood and more. "We currently believe that CHS may result from chronic overstimulation of endocannabinoid receptors in the body, leading to derangements in the body's intrinsic control of nausea and vomiting," says Torbati.

Long-term, heavy cannabis use "can change how our brains regulate nausea and vomiting", says Marieka DeVuono at Western University in Canada. "While much more research is needed to understand the link, it seems likely that endocannabinoid system impairment is underlying CHS."

Marijuana users can lower their chance of developing CHS by taking the drug less often and reaching for less-potent products. There is some evidence that using products with cannabidiol (CBD) – the non-intoxicating part of the plant – could help prevent THC-induced nausea. ▮

JAHI CHIKWENDIU/THE WASHINGTON POST VIA GETTY IMAGES

Overconsumption of THC may cause a cannabis vomiting disorder

Archaeology

Mass grave in Spain tells of the earliest known war in Europe

Michael Marshall

STONE Age people were fighting small-scale wars in Europe over 5000 years ago, earlier than thought. The conflicts took place long before powerful states formed in the region.

The evidence comes from a re-analysis of hundreds of human remains found at a burial site in northern Spain. The bones are predominantly male and many have evidence of injuries from stabbing and blunt-force trauma – suggesting they belonged to a warrior class.

"It's too large to be conflict within a community," says Rick Schulting at the University of Oxford. The sheer scale of the conflict points to early warfare, rather than just interpersonal conflicts or skirmishes, he says.

The site in question is San Juan ante Portam Latinam, a rock shelter in a valley in northern Spain. It was found by accident in 1985 when a bulldozer uncovered human remains. Radiocarbon dating of the bones suggests they were laid down between 3380 and 3000 BC, during the European Neolithic period.

J. I. VEGAS

Human remains buried at San Juan ante Portam Latinam in Spain

San Juan ante Portam Latinam is about 20 square metres in area. In that small space, researchers found densely packed human bones. They include 90 complete skeletons, more than 200 partial skeletons and thousands of seemingly isolated bones. There were also many stone weapons, including blades, arrowheads and axes. Many of the bones showed signs of injuries, and because they were all dumped together, the site was initially interpreted as the remains of a massacre.

Schulting and his colleagues have systematically re-analysed the remains. They say San Juan ante Portam Latinam probably doesn't represent a single massacre, but rather evidence of sustained conflict that was mostly conducted by young men – in other words, warfare.

The team concludes there are at least 338 people interred at the site. Of those, at least 23 per cent have visible injuries: one of the highest rates of violent injury found in prehistory. The wounds include 65 unhealed injuries and 89 healed ones, indicating prolonged conflict. The largest proportion of the injuries were attributable to blunt-force trauma, as might be caused by axes, clubs or thrown stones (*Scientific Reports*, doi.org/k3v9).

"This is a very careful and meticulous study," says Martin Smith at Bournemouth University in the UK.

There are more male remains – especially young ones – than would be expected in an indiscriminate massacre. Of 153 individuals whose sex could be estimated, 70 per cent were male. Nearly 45 per cent of these had visible injuries, compared with almost 24 per cent of the female remains. Furthermore, among remains that could be classified, 97.6 per cent of unhealed injuries were found on male remains.

Schulting and his colleagues argue that this points to the existence of a male-biased warrior class, something found in many societies. ▮

Technology

Robot swarm makes collective decisions like bees do

A SWARM of small, wiggling robots that communicate with flashing lights can make collective decisions. This is similar to the process bees use to reach consensus.

"We believe that in the near future there are going to be simple robots that will do jobs that we don't want to do, and it will be very important that they make decisions in a decentralised, autonomous manner," says Carmen Miguel at the University of Barcelona in Spain. She and her team tested how imitating bees might help with that.

When bees go house-hunting, scouts communicate their preferred locations through a "waggle dance". The more a bee is advocating for one location, the longer and more vigorously it waggles. Eventually other bees join in and they reach a consensus when a majority are waggling together. Researchers previously built a mathematical model of this behaviour, and Miguel and her colleagues used it to program decision-making rules into small robots called kilobots.

Each kilobot is a circular disc about 3 centimetres across with three spindly legs. They each had an infrared-light emitter and receiver, and a coloured LED light. Within a swarm, kilobots could move around, turn clockwise or anticlockwise and use infrared signals to exchange up to 9 bytes of information. Over more than 70 tests, the team placed 10 to 35 kilobots into a circular arena and had some of them advertise for a particular state – the equivalent of an opinion – by turning their LED red, green or blue.

"We believe that in the near future there are going to be simple robots that do jobs we don't want to do"

Team member Ezequiel Ferrero at the University of Barcelona says that across all the experiments, kilobots reached consensus within about half an hour, even when they didn't have many immediate neighbours to communicate with (arXiv, doi.org/k3xj). He says that getting the right combination of how long they spend transmitting their message and how much they walk around allowed them to make a collective decision in the end. ▮

Karmela Padavic-Callaghan

Environment

Hydrogen fuel may add to warming but it still brings benefits

James Dinneen

HYDROGEN leaking from pipes or storage tanks indirectly acts as a greenhouse gas, but there are still significant climate benefits to be had if we switch from burning fossil fuels to burning clean hydrogen.

During combustion, hydrogen emits only water vapour and heat. If produced with renewable energy, hydrogen fuel offers a carbon-free way to power processes that are difficult to run on electricity, such as steel-making. However, if hydrogen leaks into the atmosphere, it adds to global warming by reacting with other atmospheric gases.

Keith Shine at the University of Reading, UK, and his colleagues compared the impact of such leaks with the benefits of using hydrogen as an alternative to fossil fuels. They used the latest data on its warming effect, estimated at roughly 12 times that of carbon dioxide when measured over 100 years. They found that, in a scenario where the world uses lots of hydrogen produced with renewable energy – known as green hydrogen – leaks would reduce the climate benefits of the switch by only a bit – between 0.4 and 4 per cent, depending on the leakage rate (*Atmospheric Chemistry and Physics*, doi.org/k3sr).

Ilissa Ocko at the Environmental Defense Fund, a US nonprofit, says she broadly accepts the findings, but notes that hydrogen's warming effect is more significant in the short run because the gas doesn't last long in the atmosphere. In a worse-case version, Ocko says the leakage could undo something like 40 per cent of the benefits of using green hydrogen in the near term.

The calculus also changes completely if the hydrogen is made using fossil fuels, as nearly all of it is today. "We will not get the anticipated climate benefits if we don't take care of the hydrogen emissions problem," says Ocko.

Health

Tall children at greater risk of some forms of heart disease

David Cox

CHILDREN who are taller than average may face a greater risk of some types of heart disease as adults, but their stature also seems to protect them against other forms of the condition.

Among adults, being tall has been linked to a lower risk of problems such as coronary artery disease, but studies have also found that taller people have a greater risk of having an irregular heart rate.

To better understand how height may affect heart health, Tom Richardson at the University of Bristol, UK, and his colleagues used the UK Biobank database to analyse more than 454,000 adults. The team gathered information on their genetics, any cardiovascular diagnoses and their height, roughly categorised into "short", "average" and "tall". Participants were also asked whether they would consider themselves to have been short, tall or about average height at 10 years old.

Next, the researchers applied a technique called Mendelian randomisation, which uses the genetic variation that occurs among people as a stand-in for the randomisation of some trials. From this, they identified 840 genetic variants that are linked to height among children and 1201 variants associated with adult height.

A child's height may influence their later risk of a stroke

ANDRII SHEVCHUK/ALAMY

When comparing this information with participants' cardiovascular diagnoses, the researchers found that those who reported being taller than average at age 10 were more likely as an adult to develop atrial fibrillation, an irregular and often abnormally fast heart rate, or an aortic aneurysm, a swelling in the aorta artery that could burst, (medRxiv, doi.org/k3rn). This is compared with those who didn't report being notably tall at 10, but became tall adults.

1201

Genetic variants are associated with height among adults

The increased risk could be due to tall children having higher levels of a hormone called thyrotropin, which both stimulates early growth and induces certain vulnerabilities within the heart.

"One idea for a future study is to use cardiac imaging to see whether we already see alterations across different components of heart structure across the life course amongst individuals who were taller as children," says Richardson.

Sridharan Raghavan at the University of Colorado Anschutz Medical Campus, who has researched the links between height and various conditions, says the results could be a basis for investigations into what predisposes certain people to conditions like atrial fibrillation.

"There are some potential variants which share an association between height and these heart conditions, but it is still to be discovered what these relationships are," he says.

In more positive news, the researchers also found that both children and adults who are taller than average are less at risk of developing coronary artery disease or having a stroke at some point in their lives. They speculate that certain genetic variants could affect both height and some aspects of heart health. "Taller people typically have a more favourable profile of lipids or fats in their blood and a lower average blood pressure," says Richardson.

Raghavan says people who are tall may come from more privileged backgrounds, which could drive their lower risk of certain heart conditions more than their genetics. However, Richardson argues that by using Mendelian randomisation, the results can't easily be biased by factors such as socioeconomic status.

Biology

Sense of place helps sperm to succeed

SPERM change how they swim in response to different conditions in the vaginal tract, a finding that may help improve fertility treatments.

Farin Yazdan Parast at Monash University in Melbourne, Australia, and her colleagues looked at how bull sperm cells, which resemble human ones, move their tails while swimming through a mucus-like liquid, similar to that in the vagina. They found that the more viscous the mucus, the larger the motions made by the sperm (*Cell Reports Physical Science*, doi.org/k3r5).

The tails beat fastest when the environment most resembled the area upstream of the vaginal tract, when sperm approach the egg. Sperm that can't adapt to these conditions are probably less likely to fertilise an egg, says Yazdan Parast. **Jason Arunn Murugesu**

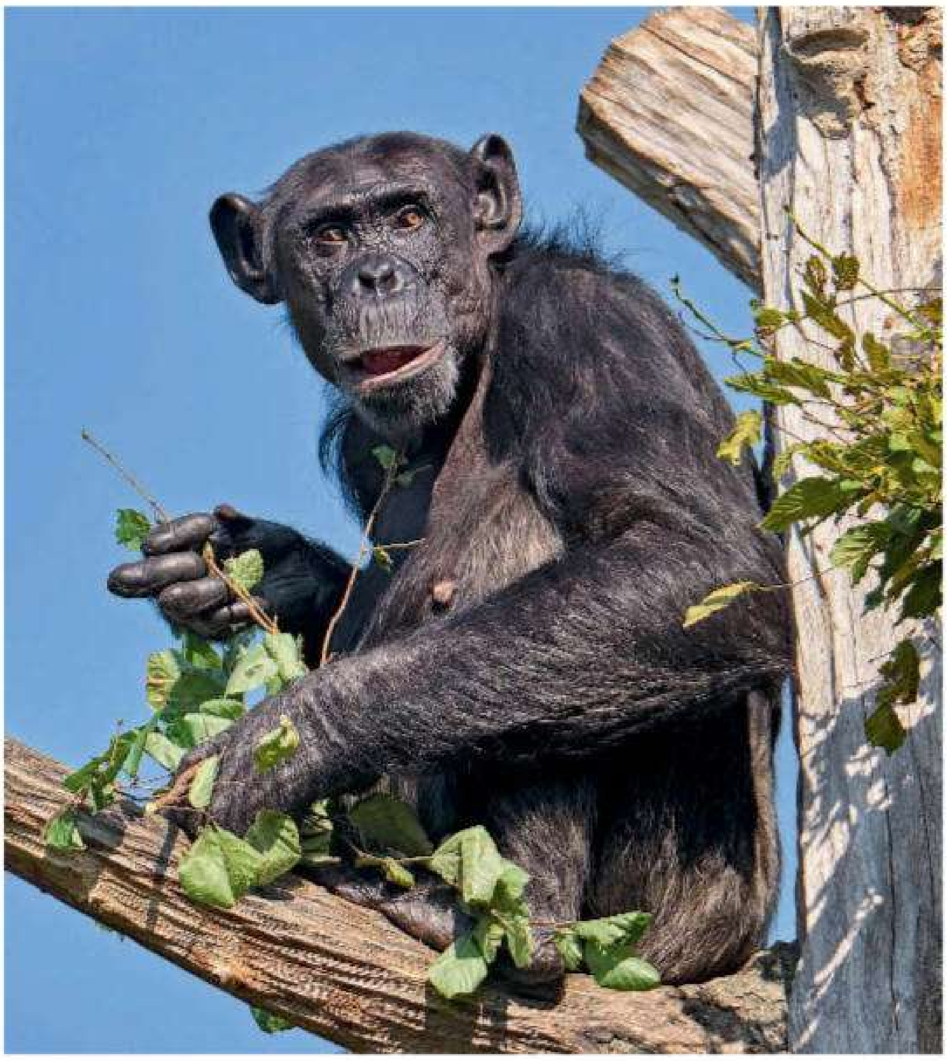
Geology

Ancient planet may lurk within Earth

THERE may be chunks of another world trapped inside ours. For decades, we have known that there are two blobs in Earth's mantle, each tens of kilometres wide, that are denser than the surrounding rock. One is beneath Africa and the other under the Pacific Ocean.

Qian Yuan at the California Institute of Technology and his colleagues used simulations to show that these blobs could be from a Mars-sized object called Theia, which is thought to have slammed into Earth, creating the moon from the debris.

The team found that rocks from Theia would have melted and sunk to the boundary between Earth's mantle and core. Over time, convection within the mantle would have slowly gathered this dense material into the two piles we see today (*Nature*, doi.org/k3r4). **Leah Crane**



ZOONAR GMBH/ALAMY

Animal behaviour

Chimp spies seek out the higher ground to beat rivals

CHIMPANZEES climb hills to stealthily gather information about rival groups and plan safe routes into enemy territory.

"Securing high ground to spy on nearby groups is an essential military strategy for humans," says Sylvain Lemoine at the University of Cambridge. Now it seems that two neighbouring groups of western chimpanzees (*Pan troglodytes verus*) that live in Taï National Park, Ivory Coast, use similar tactics.

To study their behaviour, Lemoine and his colleagues observed both chimpanzee communities, each consisting of between 30 and 37 individuals, every day for three years.

"Chimpanzees are extremely territorial," says Lemoine. "We saw regular border patrols in the periphery of their territories for both groups."

These patrol units would repeatedly stop to rest on hilltops when they approached rival land. "High ground favours good acoustic conditions," says Lemoine, who says that this behaviour suggests that chimpanzees pause to listen out for enemies.

The animals on watch then used any sounds they could hear, which included calls and drumming, to judge how risky it was to enter the other group's territory. The closer the enemy seemed, the less likely the chimpanzees were to advance onto rival land.

For example, they proceeded into enemy territory 60 per cent of the time when their rivals were 3 kilometres away, but advanced just 40 per cent of the time when their rivals were a mere 50 metres away from them (*PLoS Biology*, doi.org/gs3gpj). **Chen Ly**

Really brief

WILDFIRE IMAGE/ALAMY

Wildfire ash aids ocean microbes

Burnt material from bushfires that falls in the ocean can provide nutrients that boost the growth of microorganisms, researchers have found. Such ash is known to fertilise soil, while in rivers and lakes it can poison fish and molluscs with toxic metals. Its effects on the wider ocean ecosystem are still unknown (*Proceedings of the Royal Society B: Biological Sciences*, doi.org/k3r9).

Quest for the quectonewton

A sensor made from extremely cold atoms can detect forces as small as a millionth septillionth of the effect of gravity on an apple falling from a tree, known as a quectonewton. It could help reveal the existence of completely new forces in the future (arXiv, doi.org/k3sb).

Add salt to boost computer speed

Cooling computers using a solution based on lithium bromide salt could boost the performance of the machines by a third. The approach relies on an efficient and passive evaporation technique (*Device*, doi.org/gs3bpm).

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Views

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Culture columnist
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Comment

Time to wake up

Early school start times can be harmful to the health of adolescents. But delaying the morning bell isn't a panacea, says **Kenneth Miller**

MICHELLE D'URBANO

THIS year marks the 30th anniversary of a study that sparked a global movement to change the timing of children's school days. Published in the journal *Sleep* by Mary Carskadon at Brown University, Rhode Island, and her colleagues, this paper set out to answer an age-old riddle: why do teenagers stay up so late, and why is it so hard to pry them out of bed in the morning?

Conventional wisdom held that teens' preference for waking up and staying up later was driven by social forces – the pressures of school, the pleasures of partying. Carskadon, however, suspected that biological factors might be responsible. To test that hypothesis, she surveyed 2000 schoolchildren across the US on their preferred and actual bedtimes and wake times; the times of day when they felt most or least alert and energetic; and their physical development.

The results pointed to biology. Sixth-graders (aged 11 or 12) scored higher on "eveningness" and lower on "morningness" than younger children, even though they occupied the same social milieu – a tendency that correlated with their stage of puberty. In earlier studies, Carskadon had shown adolescents need more sleep than younger kids to avoid daytime drowsiness. Therefore, she and her team concluded, the practice of ringing the morning bell earlier at middle schools (for 11 to 13-year-olds) and high schools (for ages 14 to 18) than at elementary schools "may run precisely counter to children's biological needs".

Carskadon went on to confirm her findings using more direct methods, such as measuring levels of melatonin in teens' saliva round the clock. In response, a growing number of US municipalities began pushing back start times in middle and high schools. Further research linked such moves to higher test scores, as well as lower rates of depression, substance use, illness and vehicular accidents.

In 2014, the American Academy of Pediatrics recommended that middle and high schools start the day no earlier than 8:30am. The American Psychological Association and the American Medical Association later followed suit. In 2019, California became the first US state to pass legislation based on those guidelines. This May, Florida became the second. Meanwhile, school districts from Australia to South Korea have launched similar reforms.

Still, progress has been slow. In the US, more than 80 per cent of high schools still start before 8:30am, and 10 per cent before 7:30 am. In many other countries, 8 am remains the norm. Not coincidentally, most teens in high-income nations get far less sleep than the 8 to 10 hours that experts deem optimal for them.

Altering this status quo would surely be a step towards improving adolescents' mental and physical health. Yet later school start times alone may not be sufficient to quash the teenage exhaustion epidemic.

In the UK, where most secondary schools (for 11 to 18-year-olds) open at around 9am, drowsy students aren't rare. And even a 10am start can confer little benefit if teens are staying up till dawn on their phones, or if socioeconomic factors make it difficult to access a comfortable bed in a quiet, dark room. That is why some advocates also argue that sleep education – teaching evidence-based practices that promote and enhance sleep – should be added to school curriculums. In small studies, researchers at the University of Oxford have found that such interventions can significantly improve sleep quality, even for children from low-income households who initially report poor sleep.

After 30 years, the movement to start school later is gaining new momentum. It may yet help to solve the teen sleep crisis. But it could also wind up showing us how much we have to learn. ▮

Kenneth Miller is the author of *Mapping the Darkness: The visionary scientists who unlocked the mysteries of sleep*

Field notes from space-time

Stellar astrophysics IRL Explaining the structure and evolution of stars may seem as esoteric as can be, but there are plenty of applications in the real world, says **Chanda Prescod-Weinstein**

Chanda Prescod-Weinstein is an associate professor of physics and astronomy, and a core faculty member in women's studies at the University of New Hampshire. Her most recent book is *The Disordered Cosmos: A journey into dark matter, spacetime, and dreams deferred*

RECENTLY, I was giving a tour of the University of New Hampshire's department of physics and astronomy to a guest who isn't a scientist. Among the many questions he asked was: "How does this stuff show up in the real world?" The kind of stuff I do, I explained, is mostly just knowing things for the sake of our big-picture understanding of the universe and our place in it.

Later, I realised I had made a mistake in not giving a practical example based on the class I am teaching, an introduction to stellar astrophysics. The topic can seem as esoteric as it gets, because what use could we possibly have for equations that describe the structure and evolution of stars?

The first answer to this is that almost every element in the periodic table is made in stars, star deaths, stellar remnants (what is left after a star dies) and collisions between stellar remnants.

But there are more practical considerations: understanding our local star is essential for our electricity-dependent world. Space weather is a very real phenomenon that can have serious consequences for our electrical grids. In March, Mpho Tshisaphungo, head of space weather for the South African National Space Agency (SANSA), announced a forecast for a coronal mass ejection (CME) that could disrupt electrical grids.

A CME with relevance to Earth occurs when the sun's atmosphere spits out plasma (a sea of charged particles acting in concert), leading to magnetic fields being stretched out to the point of interacting with our planet's magnetic field. These temporary changes to Earth's magnetic field can disrupt satellites, radio transmissions and electrical transmission lines, with the potential to damage power distribution facilities.

Tshisaphungo and his team originally forecast a mild CME; in actuality, the storm ended up being more extreme. This discrepancy isn't a failure on SANSA's part, but rather a sign of how research into stellar structure and evolution has significant practical importance. Predicting and protecting the grid from harm requires monitoring the sun and using mathematical models to predict what it might do next.

In a past column, I talked about the importance of using observational tools like NASA's GOES satellite network to monitor solar activity. While such tools provide essential data about the sun's current status, they don't explain exactly how solar phenomena influence Earth's magnetic field. This is where theorists come in, to try to figure out the mechanisms through which CMEs affect our planet's magnetic field and the region of space where it is typically the dominant magnetic field, the magnetosphere.

> **"Space weather is a very real phenomenon that can have serious consequences for our electrical grids"**

It is worth pausing to say that, yes, Earth is a giant magnet! But it is a weak one. A refrigerator magnet is about 200 times stronger than the geomagnetic field that reaches from Earth's interior out into space beyond the atmosphere. This magnetosphere has a dynamic relationship with our atmosphere: they affect one another. Because of its electromagnetic properties, the magnetosphere changes how charged atomic ions behave, and there is a layer of the upper atmosphere called the ionosphere that is comprised entirely of ions.

Clearly, we have a big picture sense of what it means for the ionosphere and magnetosphere to interact and affect one another. But the devil is in the details. We know they create an environment where winds of charged ions form. Today, scientists actively work on trying to explain how ionised hydrogen and oxygen are accelerated in these winds, because understanding this behaviour can provide insight into the exact mechanisms of ionosphere-magnetosphere interactions, as well as how space weather like CMEs affects them.

Imad Barghouthi at Al-Quds University in Palestine has proposed a promising model based on an idea known as wave-particle interactions (WPIs). Despite the name, this isn't a quantum mechanical idea. Instead, WPIs look at how particles like ionised hydrogen or oxygen behave when they are in a bath of plasma waves. Various researchers have explored WPIs in relation to the acceleration of hydrogen and oxygen ions.

Barghouthi and his team have added their own twist to this idea, suggesting it is important to correctly model how the particles spread out by showing that this spread is dependent on their speed. In a 2008 paper, Barghouthi used computer simulations to demonstrate that his model fitted the data better than other models did. Of course, this isn't the end of the conversation, but it is work like this that brings stellar astrophysics into the real world and helps us all live better under the gaze of our occasionally messy sun. ▮

Chanda's week

What I'm reading

Robin Bernstein's Freeman's Challenge: The murder that shook America's original prison for profit.

What I'm watching

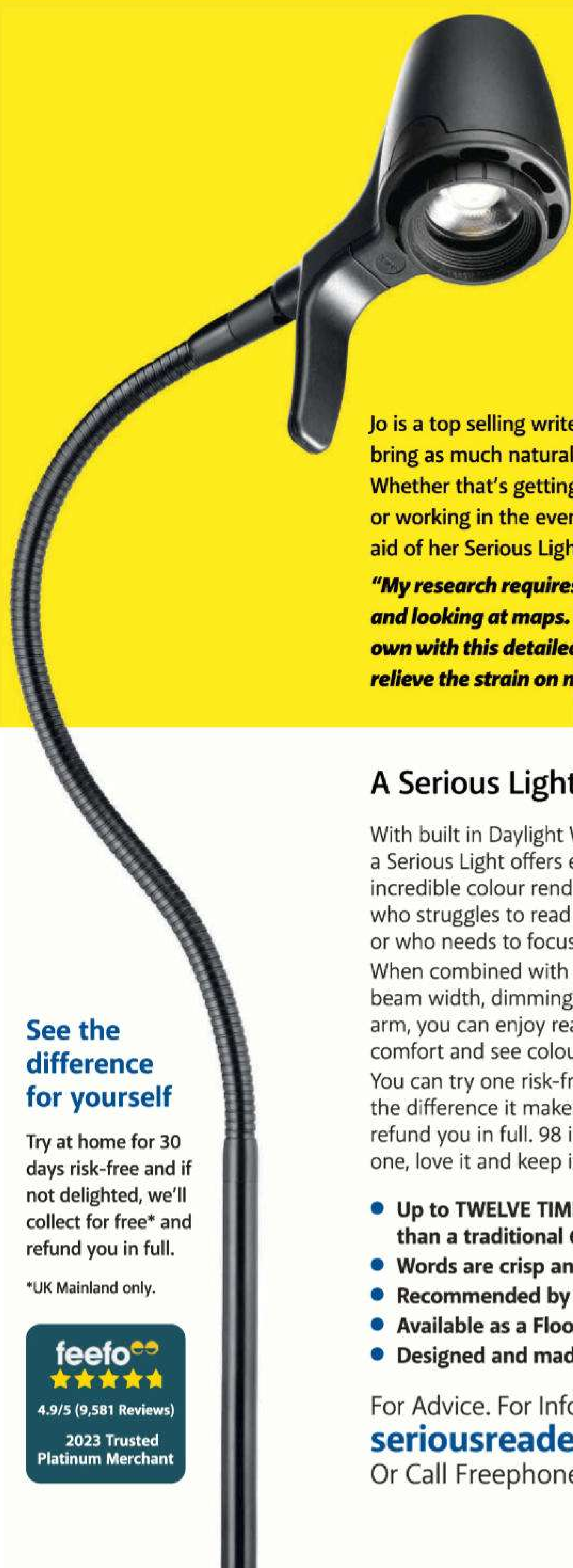
I've been catching up on Coronation Street.

What I'm working on

Learning about applications of astrophysics and electromagnetism by reading some of Imad Barghouthi's papers.

This column appears monthly. Up next week: Graham Lawton

A BETTER LIT LIFE



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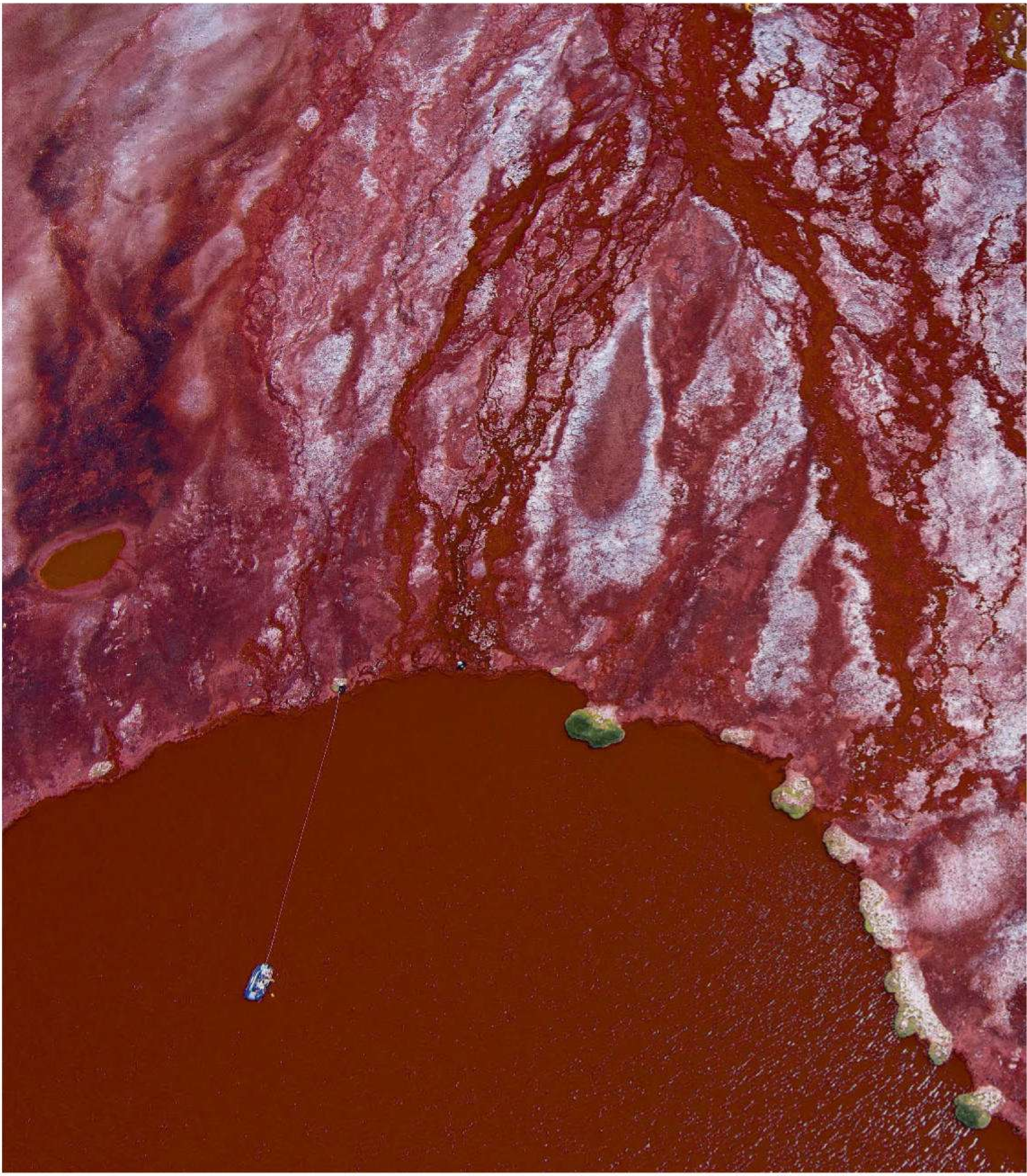

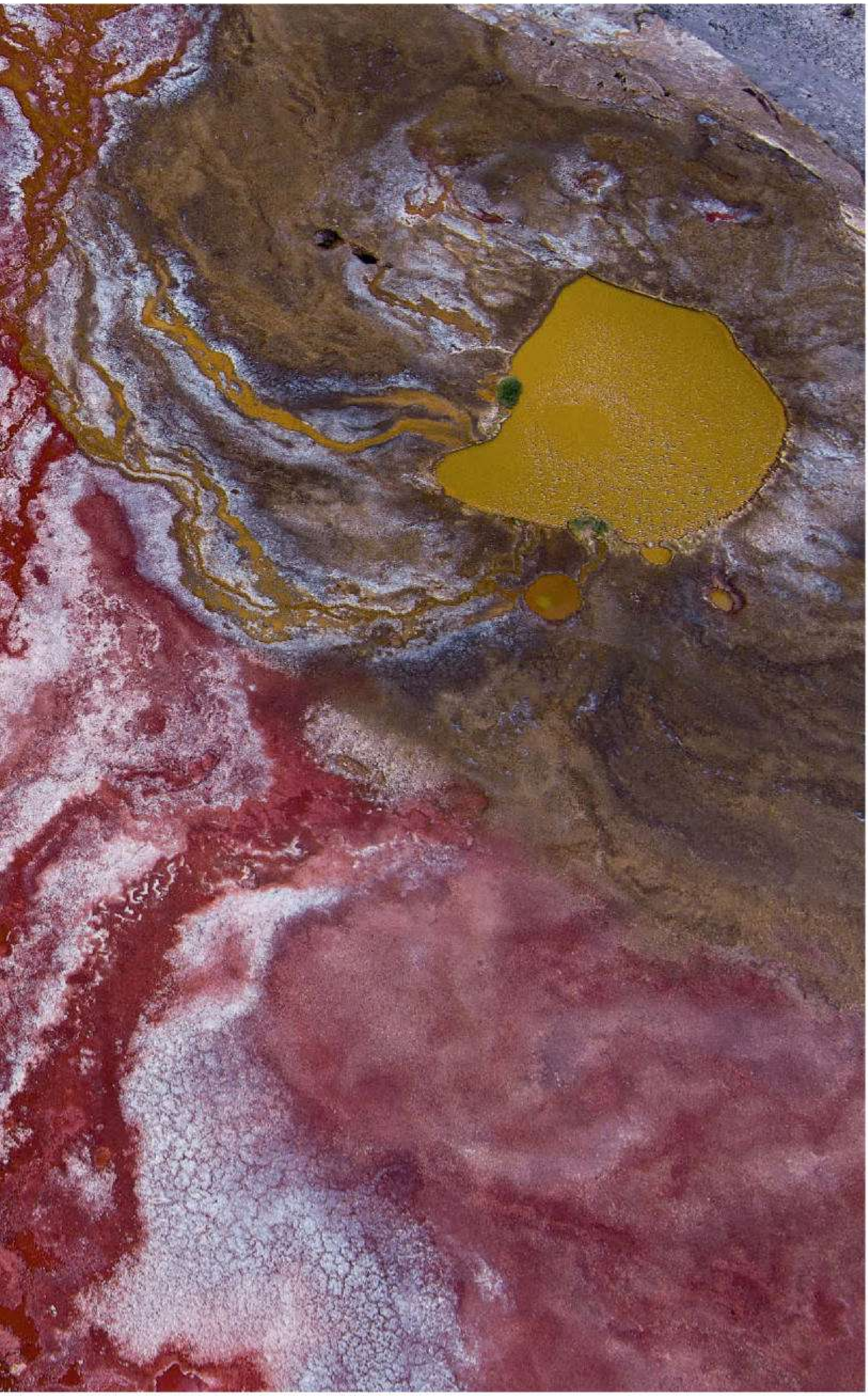

Cradle of life

Photographer Olivier Grunewald

THIS spectacular snapshot of a landscape in the Salar de Atacama, a salt flat in northern Chile, was captured with a drone by photographer Olivier Grunewald.

He has documented the journey of researchers from the French National Centre for Scientific Research (CNRS) and the Chilean University of Antofagasta into the farthest reaches of the 3000-square-kilometre salt flat, at altitudes of up to 4000 metres, as they undertake a mission to probe the beginnings of life itself.

They are here because the salt flat's acidic, hypersaline waters – which render it inhospitable to virtually all life – are home to a remarkably diverse range of microorganisms that may hold clues about the primitive life forms that dominated early Earth.

These species might provide further evidence that animals, plants and fungi are descended from a group of microbes called archaea, particularly a subgroup called Asgards, with which we share some of our genes.

Some members of the team are shown below collecting water from Laguna Roja (Red Lagoon), also shown in the bottom left of the main image. Its colour is due to sodium chloride, arsenic and borax salts, as well as red pigments secreted by certain archaea.

Gege Li

Editor's pick

Here's how to help our urban trees thrive

21 October, p 34

From Craig Sams, Hastings, East Sussex, UK

Urban trees planted in Stockholm, Sweden, have been shown to be healthy, and the methods used are now being applied in the UK with growing success. The Stockholm Tree Pit system captures rainwater from roofs and roads, then channels it into a tree pit containing crushed granite and biochar. This allows for ingress of both water and oxygen, and the biochar ensures a resilient soil microbiome. It was created by Björn Embrén, Stockholm's tree officer, and has significantly boosted the success of urban trees.

From Ed Carrington, Hexham, Northumberland, UK

Fallen leaves from urban trees are often swept up and disposed of by street cleaners or residents, removing a valuable source of leaf litter, which forms the top layer of soil in forests or woodland. Returning this as a mulch, in addition to added topsoil, could help solve some of the problems you report. In addition, authorities don't allow decaying or dead trees to remain on streets for obvious reasons, again removing a vital source of microorganisms that contribute to leaf litter.

No mention was made of earthworm populations in urban tree root systems or surrounding soil. Earthworms are known to spread fungi, both beneficial and otherwise. In general, their presence seems to increase the occurrence of beneficial mycorrhizal fungi.

Why do so many fight shy of a career in engineering?

28 October, p 21

From Gordon Jackson, Stockport, Greater Manchester, UK

Hayaatun Sillem is correct in her assessment of the shortage of graduates in engineering.

The lack of women in this walk of life is a problem that has consumed a forest full of research papers and focus group reports over the years, but to little effect. It isn't simply that engineers are portrayed as either the greasy rag brigade or shown in hard hats on building sites, but that the job is viewed as low-paid grunt work needing high-level qualifications.

I once ran a course aiming to encourage women onto my institution's engineering courses. It was a great success until the end, when I asked if they would now join us on one of our BTEC courses. Every one answered by saying that there are easier ways to earn a living.

You can cast processed foods in a positive light

28 October, p 40

From Eric Kvaalen, Les Essarts-le-Roi, France

Why so much cynicism over "ultra-processed" foods (UPFs)? You report claims that the food industry's goal "is to maximise profits by cajoling consumers to abandon freshly prepared food". Why not say that the industry gives us the possibility of buying ready-to-eat food instead of having to do all the processing ourselves? And why say "they are engineered to have craving-like palatability" instead of "they are developed to be delicious"?

And after describing a key experiment, you say that "the conclusion is obvious: UPFs 'lead people to overeat calories'". Yes, but it doesn't show that this was because they were ultra-processed. I would say the conclusion is obvious – people like eating hot dogs and French fries more than plain, raw fruits or vegetables.

When you say that the highest consumers of UPFs were 1.6 times more likely to die during a study, that ignores confounding factors. They surely ate more calories, so you should probably blame it on that, not the ultra-processing.

From Rosalind King, Penrith, New South Wales, Australia

Perhaps there is no more ultra-processed food than lab-grown meat and plant-based alternatives.

Applause for renewables, but more must be done

Leader, 28 October

From Peter Cross, London, UK

You rightly laud South Australia's push to decarbonise its electricity generation, but, in common with so much reporting around net zero, the implication is that we will hit this target when all of our electricity generation is carbon-free. Global primary energy consumption in 2022 was around 179,000 terawatt-hours, of which about 137,000 TWh, or 82 per cent, came from fossil fuels. Electricity generation accounted for only about 28,500 TWh, or 17 per cent, of this global fossil fuel use.

Older homes may never be suitable for heat pumps

Letters, 28 October

From John Kitchen, Kettering, Northamptonshire, UK

S. W. Shaw calculates that around 9 million UK homes may have converted to using heat pumps in the next 15 years. However, millions of homes here are Victorian and broadly aren't suitable for heat pumps. Beyond those 9 million conversions, to really make progress towards net-zero housing, we may have to bulldoze all Victorian houses.

Taking the carbon tax to its logical conclusion

Letters, 21 October

From Simon Conolly, Cork, Ireland

There have been welcome ideas from readers relating to carbon taxes, but an important added ingredient is needed to make them work, to prevent "carbon leakage" via the import of goods with high embedded carbon.

To that end, the European Union has created the Carbon Border Adjustment Mechanism (CBAM). It demands that the carbon footprints of carbon-intensive imported goods are accounted for. From 2026, these have to be paid for by purchasing CBAM certificates. This mechanism needs to be applied worldwide to ensure equitable sharing of emission reductions.

What chance is there of world trade agreements adopting this? Perhaps they will, if a critical mass of major trading partners does so.

Vape waste is a big problem too

21 October, p 14

From Paul Rendell, Tywyn, Gwynedd, UK

I am concerned about the impression that discarded toys generate more e-waste than vapes. While it is true that toys make up the majority of this in landfill, I suspect vapes make up the majority outside landfill and fly-tipping sites. Some ex-smokers discard them like cigarette butts.

Could we solve the riddle of the Sphinx for good?

4 November, p 13

From John Davies, Lancaster, UK

You raise the idea that there may be a harder core to the Great Sphinx of Giza, the shape of which was formed by wind erosion. Couldn't this question be easily answered by the use of ground penetrating radar? If there is no hard core, then the riddle remains!

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Migration: From fury to fact?

Migration divides us like little else. Perhaps we should shut up and read a book by someone who has spent decades examining the evidence, says **Simon Ings**

ALEJANDRO CEGARRA/BLOOMBERG VIA GETTY IMAGES

Migrants cross the Rio Grande in Mexico, en route to the US

Book

How Migration Really Works

Hein de Haas

Viking Books

EVERYONE who starts geographer Hein de Haas's *How Migration Really Works* will have opinions about migration – few will finish with their preconceptions intact.

Drawing on three decades of research from his time at the University of Oxford and the University of Amsterdam, de Haas shows that everything we think we know about migration is wrong.

This isn't because migration is an especially complex matter, but because economic and political interests, on both the left and the right, have lost sight of the evidence – that is, when they haven't actively misrepresented it.

De Haas explores trends in global migration patterns, examines the impacts of migration on both destination and origin societies and closes with a series of fairly devastating takedowns of popular ideas.

The problem runs deep. Take the frequently quoted figures released by the United Nations High Commissioner for Refugees (UNHCR), which "seem" to show that the global total of displaced people increased nearly 50-fold from 1.8 million in 1951 to 100 million in 2022.

What explains this shocking rise? Globalisation? War? Climate change? Issues with the statistics?

"What appears to be an unprecedented increase in refugee numbers," de Haas explains, "is in reality a statistical artefact caused by the inclusion of populations and countries previously excluded from displacement statistics." UNHCR's current figures are now truly global. But its 1951 baseline figure was drawn from a database covering just 21 countries.

It is the direction of migration after the second world war that some in Western nations have found so disconcerting. The numbers have hardly changed. At any time, around 3 per cent of the world's population are migrants. A tenth of those are refugees. The figure for unsolicited border crossings (de Haas refuses to use the term "illegal crossings", as it doesn't capture the legal position outlined in the UN Refugee Convention) fluctuates erratically, depending on labour demand in destination countries and conflict in origin countries, but the underlying number remains stubbornly consistent.

> **"At any time, around 3 per cent of the world's population are migrants. A tenth of those are refugees"**

If migrations levels are stable, historically, why all the emotion? De Haas pulls no punches: "Although they may advocate very different solutions, politicians from left to right, climate activist and nativist groups, humanitarian NGOs and refugee organizations and media have all bought into the idea that the current era is one of a migration crisis."

That this results in staggeringly wrong-headed policy-making comes as no surprise – witness massive US investment in border enforcement since the late 1980s. This, writes de Haas, has "turned a largely circular flow of Mexican workers going back and forth to California and Texas into an 11-million-strong population of permanently settled families living all across the United States". They stay because it is too costly in every sense to keep moving.

Catastrophising migration also has a cultural impact. In host nations, nightmare migration scenarios are peddled to tickle every political palate. An international cabal runs people smuggling. (No evidence.) The mafia are trafficking young women for sex. (No evidence.) Migration flows mainly from the poorer southern hemisphere to the wealthy north. (Wrong.) Migration lifts all boats. (No. It overwhelmingly benefits the already affluent.) Where is the scenario that credits migrants themselves with connections, ambitions, foresight, agency or even intelligence?

How Migration Really Works is a carefully evidenced critique of a political culture that would rather use migration as a domestic passion-play than treat it as an ordinary and governable part of civil life. To be pro and anti immigration is to miss the point entirely. You wouldn't ask an economist whether they are for or against the economy, would you?

We are constantly told we need "a big conversation" about immigration. I am rereading this book (something crabbed reviewers never normally do). Until I am done, I am going to keep my big mouth shut. ▮

Simon Ings is a critic and writer based in London

The Twitter story

This tale of Elon Musk's acquisition of Twitter may end up a hit as a movie – but not as a book, finds **Chris Stokel-Walker**

Book

Breaking Twitter

Ben Mezrich

Pan Macmillan

AT TIMES over the past 18 months of courtship, falling out and eventual forced marriage between the mercurial billionaire Elon Musk and Twitter, the events of his takeover of the platform he calls the "de facto public square" seemed to come straight out of a movie.

Little wonder, then, that author Ben Mezrich has decided to document the chaotic whirlwind that surrounded Musk before, during and after his hostile takeover of Twitter, now called X.

Mezrich is renowned for churning out business books that are easily translated into Hollywood movies. His book *The Accidental Billionaires*, about Facebook's genesis, became the hit movie *The Social Network*. And his *Bringing Down the House*, about MIT mathematicians who swindled Las Vegas casinos out of millions, became the film *21*.

Larger than life: Elon Musk dressed up for a Halloween party in 2022

TAYLOR HILL/GETTY IMAGES

Undoubtedly, *Breaking Twitter* will soon get the same treatment. After all, who is a better lead character than Musk himself?

Whether a book written with half an eye on making it easy to turn into a pacy, 90-minute movie is an enjoyable read is another question. Hollywood producers on the lookout for an enticing story will appreciate its casual style and the dramatic prose that can be turned into powerful imagery. But readers wanting to learn what actually happened leading up to and following Musk's $44 billion purchase of Twitter may do well to read other books, including veteran tech journalist Walter Isaacson's doorstop of a biography of Musk.

The issues come early. Before we even get into the narrative, the reader is presented with a note "from Bestselling Author Ben Mezrich", designed to sugar the pill: the book, it turns out, is based on dozens of interviews and thousands of pages of documents, but it might not all be true.

"Some dialogue has been reimagined," Mezrich writes. "The dates of some of the events have been adjusted or compressed." Composite characters have been created. "At some points… I employ elements of satire," the author writes, without clarifying what that means for the truth.

Later on in the note, Mezrich comes clean. He says that some of what he writes is "based on my own speculation", alongside his reporting. Yet it is never clear which is which, so the reader is left confused about the veracity of some of the more outlandish scenes – an issue compounded by Musk's life being so over the top that fact and fiction often look like they could be interchangeable.

In at least one chapter, which starts "It might have looked something like this" and continues with a cacophony of conditional phrases, it is clear that this is nothing more than the author freestyling. But when those "mights" and "mays" disappear, it is less clear how closely Mezrich is hewing to reality.

And perhaps because of time constraints – given it involved rapidly turning round a story that took place so recently – at times, the style feels like a parody of itself.

Take a tense scene in April 2022 as Twitter CEO Parag Agrawal learns about Musk breaking cover with his takeover bid. This collapses under the weight of clunky prose as text messages become "tiny packets of excited electrified molecules streaming through the air of [Agrawal's] sleepy neighbourhood and plunging into the sophisticated hunk of Apple engineering nestled in a fold of pocket by his chest". Hunter S. Thompson this is not.

Breaking Twitter is a confusing book. Whether that is a deliberate move to mimic Musk himself or just an accident is never clear.

It will make a great movie. But as a book, it frequently falls down. ▮

Chris Stokel-Walker is a technology writer based in Newcastle upon Tyne, UK

New Scientist *recommends*

Gerardo Bandera
Deputy audience editor
New York

I have been listening to the audiobook of **Being You: A new science of consciousness** by Anil Seth (pictured). This is a fascinating exploration of his idea that consciousness is the result of the biological processes of our bodies and that the sensation of selfhood – of being "you" – and our sense of reality itself emerge from what he calls "the brain's controlled hallucination", based on predictions of the body's internal state.

ALBERTO VALDES/EPA-EFE/SHUTTERSTOCK

Seth draws on research from his own lab and discusses competing ideas about neuroscience and philosophical debates that have grappled with the enigma of consciousness over hundreds of years.

I am also tackling Robert Musil's modernist novel **The Man Without Qualities**. Set in Austria in the early 20th century, this 1500-page book explores how people contended with the shift in values caused by scientific theories of evolution and the unconscious, which – much like Seth's ideas – revealed the controlled hallucination of the self.

The sci-fi column

Doom is booming *The Future*, by Naomi Alderman, takes us on a wild ride towards the end of the world, woven around a deep meditation on why we crave this catastrophe so much. Even its twists have twists, says **Sally Adee**

Sally Adee is a technology and science writer based in London. Follow her on Twitter @sally_adee

Book

The Future

Naomi Alderman

Simon & Schuster

Sally also recommends...

Book

System Collapse

Martha Wells

Tordotcom

The runaway success of the Murderbot series is down to its unique vibe, best described as "cosy Terminator", and the eighth book is a crowd-pleaser. Just don't read it as a standalone.

SHUTTERSTOCK/MARK PLUMLEY

Is there a way out in a world obsessed with prepping for doom?

YOU may have heard this old story. Two mid-20th-century satirists, Kurt Vonnegut and Joseph Heller, walk into a hedge-fund party thrown by a billionaire. Vonnegut, probably holding a drink, tells Heller that the host made more money in a single day than Heller has from every sale of his novel *Catch-22*. Heller shrugs. "Yes," he replies. "But I have something he will never have: enough."

Fifty years later, no one has enough, especially not the people who have everything. Their latest obsession is how to keep it all after the world ends, which is becoming an increasingly inevitable consequence of all that hoarding and all those billionaires. Talk about a Catch-22!

In his non-fiction *Survival of the Richest*, futurist Douglas Rushkoff recalled being buttonholed by five such people demanding answers to questions like how to stay affluent after money has lost all value, and how to force your hired security to prioritise you over their families when it is time to decamp to the bunkers. Our reality is getting hard to satirise.

But with her new novel *The Future*, set perhaps a decade away, Naomi Alderman proves she is up to the task. The apocalypse industry is thriving; it is a boom time for end times. Prepper life has taken over pop culture, in an end-stage capitalism reductio ad absurdum. There are self-erecting tents; revolutionary smart fibre jackets; PR junkets for secure survival spaces that you, too, can access for only $7000 a year.

> **"The future is getting more uncertain and we are uniquely ill-equipped by evolution to handle uncertainty"**

Sorting the good quality products from the bad is Lai Zhen, a scrappy survivalist influencer whose bona fides are bona fide: she spent adolescence in a British-run refugee camp. Her life is thrown out of kilter by an unexpected whirlwind romance with the enigmatic Martha Einkorn, right-hand woman of one of the tech titans wielding disproportionate control over the fate of the world (a pitch-perfect golem moulded from equal parts Elon Musk, Jack Dorsey and other Silicon Valley glitterati). Martha impulsively gives Zhen a gift only ever meant for the most exclusive. It saves her life. It ends up chasing her around the world. It may save her from the apocalypse. But what kind of apocalypse?

The past year or two has been a strange time in literary sci-fi. The classics have reentered the present through retellings of everything from *Nineteen Eighty-Four* to *Antigone*. Alderman goes straight for the Old Testament. The story of Zhen and Martha isn't linear, but interspersed with flashbacks and posts that appear on a survivalist forum, along with what can only be called Bible study.

By rights, this book should be a mess. But it is glorious. The main thrust is powerful enough to hold the rest in place. The religious motifs are spare and pointed, in the service of a deceptively simple goal: to illuminate the human weakness that got us here.

The future is getting more uncertain and we are uniquely ill-equipped by evolution to handle uncertainty. The pickle is, planning for the end of the world just hastens its arrival.

If that were the book's big insight, *The Future* would join the teetering pile of dystopian sci-fi that seems to grow taller each year. But this tale has a twist landing it squarely in the opposite camp, often called solarpunk. This book is glorious precisely because Alderman has the imagination (including moral imagination) to take us out of the doom loop. May it inspire many copycats. ■

EMERGENCY SURGERY

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Jessica Comi (left) and MSF surgeon Dr Federica Lezzi extract a bullet from a patient shot just above the knee during fighting in the Sudanese capital. Bashair hospital, Khartoum, 13 May. Photograph © Ala Kheir/MSF

JESSICA COMI IS AN OPERATING THEATRE NURSE WHO WORKED FOR MSF IN KHARTOUM, SUDAN.

"We arrived in Khartoum on a Monday and started operating at noon the following day. The first week was incredibly challenging.

Every time we heard explosions, we got ready for a mass casualty incident – a situation where lots of wounded people arrive at the same time. You never know if it will be 20 or 40 or 100 patients. One day, 127 patients arrived in a short space of time after a series of explosions.

Very quickly we were inundated with wounded men, women and children. Seventeen people were dead on arrival. The emergency room was full, the two operating theatres were full. In one theatre, we were trying to manage the most complex cases; in the second, we were working on cases that were a bit less complicated. That day, we ran the operating theatres until four or five in the morning. We worked non-stop.

War surgery is complicated. Working with wounded patients brings a lot of challenges and, if you aren't used to doing this type of surgery, it can be especially difficult. You need to know the potential risk for a patient if they are not treated immediately – risks such as infections or losing a limb or haemorrhaging. Bullets and shrapnel are dirty and they create massive wounds, so in a war zone you treat every single wound as already infected. These injuries are complex and you need to act quickly. Our team was experienced and that expertise made a big difference.

Depending on the kind of wound, some patients need multiple surgeries and can take many days to recover. Others may need even longer treatment – taking weeks or sometimes months.

As the conflict continued and more people heard that the hospital was open, we started to see more patients, particularly women and children.

I have worked a lot in war zones, and this was probably my most challenging assignment. But it was very special how the team worked through the challenges together. You could feel that we were all working for one reason – and that was to save lives."

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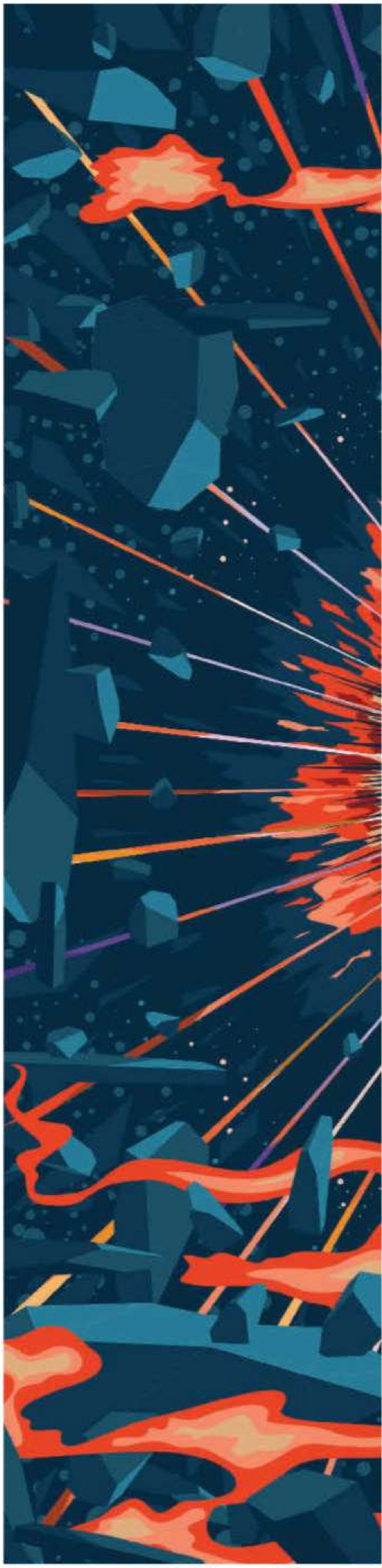
MSFR0048

The other big bang

The enduring mystery of dark matter has led some physicists to propose that it was forged in a second moment of cosmic creation, says **Stuart Clark**



GILLES & CECILIE STUDIO

POP the kettle on. Sit down and listen closely to the bubbles of water vapour as they expand, collapse and collide. You have just run an experiment simulating the big bang – the very origin of the universe – and you may also have solved the mystery of how the cosmos got its dark matter.

Well, sort of. Because by mulling over colliding bubbles on a cosmological scale, physicists are finding cause for speculation about fresh sparks of cosmic creation. It is possible, they say, that in the weeks after the big bang there was a second, similarly profound moment of transformation. This one may have spawned monstrous shadow particles trillions of times the mass of those that make up normal matter and could make sense of the mysterious, invisible matter that seems to hold galaxies together.

As outlandish as it might sound, the concept of a "dark" big bang is broadly in line with a quiet revolution that is already under way, as cosmologists rewrite what we think of as the standard big bang to account for multiple distinct "phase transitions", each leaving its mark on the cosmos. What's more, we now have the tools to test this idea by peering into the universe's earliest moments and untangling the faint ripples produced by these profound primordial shifts.

If we find evidence for the dark big bang among them, it would not only transform our view of the early universe, but also offer fresh clues about the nature of dark matter and how we might finally unmask its identity.

We think that dark matter exists because it solves several astronomical headaches. Galaxies in clusters orbit each other faster than they should, suggesting there is another source of gravity in the universe. Likewise, individual galaxies form prematurely and their outer regions rotate too quickly. These observations point to the existence of giant haloes of invisible matter whose additional gravity glues galaxies and clusters together. But even though we estimate dark matter to be five times as abundant as normal matter, we have never identified the particles that comprise it.

For 40 years, physicists have been building elaborate detectors to that end. Whatever dark matter particles are, Earth should intercept some of them as it moves through the Milky Way. Most of these experiments have been searching for weakly interacting massive particles, WIMPs for short. As well as interacting via gravity, these hypothetical particles would also feel the weak nuclear force, one of the four fundamental forces of nature. This means that WIMPs, if they exist, should interact with atomic nuclei. So, physicists

closely observe large vats of dense liquid, hoping for the telltale flash of a dark matter particle colliding with a nucleus in one of them. Despite ever more creative experiments and expanding the search to novel kinds of potential dark matter, a bona fide detection has evaded us.

But our failure to find these particles so far may point to a useful, if uncomfortable, truth about the nature of dark matter, says Katherine Freese at the University of Texas at Austin. It is possible that it doesn't feel the weak force at all, in which case gravity offers the only connection with normal matter. This has been dubbed a "nightmare scenario", as gravity is so feeble on the scale of individual particles that detection becomes near impossible. Yet Freese has taken it as a reason to think again: if we can't find dark matter, then perhaps it is time to revisit our assumptions about how it was created, in the hope that this could offer new insights into how dark matter manifests today. "People always assume everything is created at the same time in a single big bang, but who really knows?" she says.

In February, Freese and her colleague Martin Winkler proposed that there was a second big bang in the weeks after the normal big bang. They called this a "dark" big bang on the basis that it would have created dark matter in a distinct process from that which produced the particles and forces that we know of. This might sound absurd, but there are good reasons to think that we have misunderstood what was going on in the very early universe – including what we even mean by the big bang.

It was actually an opponent of big bang cosmology, Fred Hoyle, who coined the term in 1949, apparently to deride the idea that all matter and energy came into being at a single moment. This infinitely hot and dense point, proponents said, gradually expanded into the vast and varied universe that we see around us today. As improbable as that seemed to Hoyle, physicists found decisive evidence for the big bang in the 1960s. They discovered a sea of radiation called the cosmic microwave background (CMB), and this can only be explained by a universe that expands and cools.

But the big bang model was soon beset by problems. The temperature of the CMB is incredibly uniform across the night sky. Like cold water spreading through a hot bath, it takes time for photons, the particles that mediate the electromagnetic force, to even out the CMB throughout the cosmos. But not enough time has elapsed since the big bang for regions on opposite sides of the universe to equalise. To solve this puzzle, physicists ›

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added a burst of extreme expansion after the big bang, called cosmic inflation, to smooth out temperature variations.

Cosmic inflation is a phase transition, similar to the energy shift that happens when your kettle turns water into steam. Physicists have since realised that phase transitions could have suddenly changed the character of the early universe in many other ways. Similar cosmic shifts are thought to have created fundamental particles out of the energy of empty space-time, like water drops forming in a dense fog, and separated the four forces of nature out of a unified force that preceded them. More speculative phase transitions, meanwhile, are suggested to explain mysteries like dark energy – the unknown force making the universe expand faster and faster.

Seismic shifts

These days, most cosmologists find little use for the vague notion of a big bang at the beginning of time. Instead, phase transitions have come to the fore. The "hot big bang" is the umbrella term now used for the knotty series of energy shifts that happened after inflation. "Old school big bang cosmology has been superseded by what's now called inflationary cosmology," says Kai Schmitz at the University of Münster in Germany, but the details of this unstable and fluctuating early period are still up for grabs. "There's still a lot of freedom in reassembling different ingredients," he says.

Given this freedom, Freese and Winkler's addition of another big bang to the mix – metaphorically switching the kettle on – is perhaps not quite the giant leap of faith that it might first appear to be. The dark big bang becomes plausible because the particles it creates only influence the universe that we see via gravity. "We assumed that there are two sectors of the universe," says Freese – one that creates the particles in the standard model of particle physics, our current best theory of particles and their interactions, and one that creates dark matter.

According to Freese, so long as the dark big bang happens within a month of the hot big bang, its influence on the structure of galaxies and clusters that we observe today is minimal. "You have to be absolutely sure that you don't mess with the standard evolution of cosmology," she says.

When it comes to the kinds of dark matter that the dark big bang would create, Freese and Winkler's calculations suggest at least three different types of dark matter particles could be formed, all of them weird, but some even weirder than the others. "The heaviest ones are very strange," says Freese.

To produce the most massive particles, the phase transition must be abrupt, which creates expanding bubbles that carry the system from one state to the next. When these bubbles collide, they release their energy. This is like the hissing noise you hear as the kettle begins to boil and thousands of tiny bubbles emerge. In this sort of dark big bang, the bubbles are so energetic that it would be possible to produce particles 10 trillion times the mass of a proton. To reflect the monstrous size of these dark matter particles, Freese and Winkler call them "darkzillas" – in a play on the name of the fictional Japanese monster.

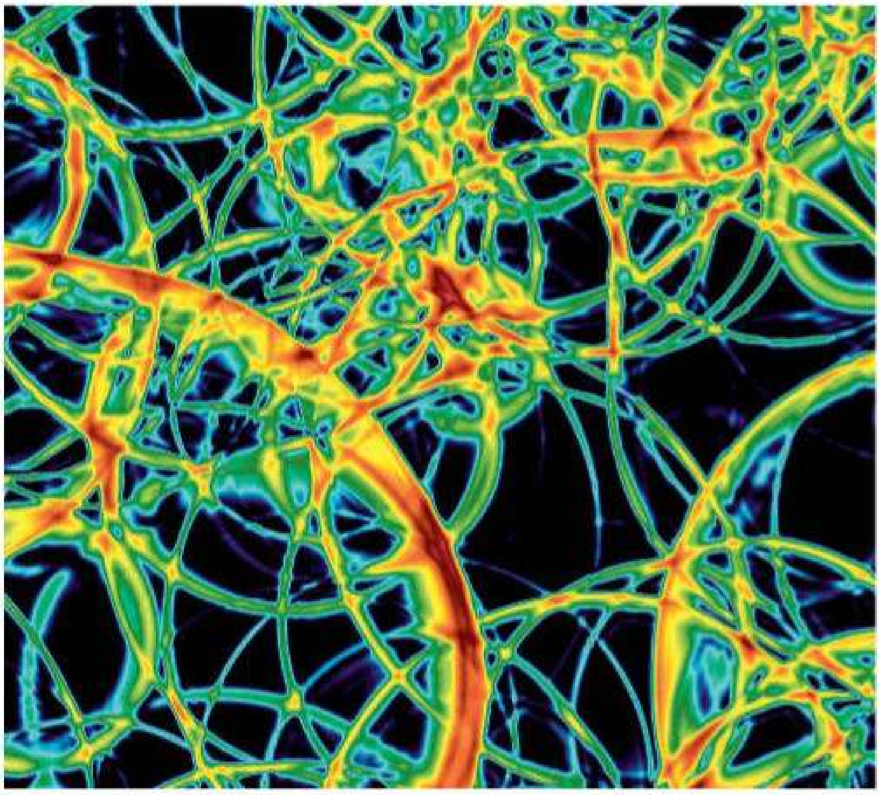
If the phase transition is gradual, on the other hand, then the dark big bang produces lighter particles. The first kind of such particles are analogous to the WIMPs that traditional dark matter experiments are searching for. These dark WIMPs would interact with dark versions of the forces of nature, such as dark electromagnetism, which creates dark photons. If these dark forces don't exist, then the dark WIMPs would no longer be able to balance their energy by absorbing and emitting dark photons. Instead, you end up with an especially ghastly sounding particle called a dark cannibal. Without any forces of nature to maintain equilibrium, these particles would engulf each other whenever they collide. "Those are some of the possibilities. There are probably more," says Freese.

This isn't the first time a hidden sector of dark particles has been proposed. Dark photons and sterile neutrinos, for instance, have long been suggested as dark matter candidates that only feel the force of gravity. Several researchers have already proposed creating dark matter through colliding bubbles in phase transitions, too. Others use phase transitions to explain the creation of dark matter out of primordial black holes or such peculiar phenomena as "quark nuggets".

"If you go to the arXiv preprint server, you'll see lots of proposals for phase transitions," says Schmitz. "What's special about [Freese and Winkler's] proposal is that their dark sector is extremely dark," he says, meaning that there is nothing but gravity joining the light and dark sides of the universe.

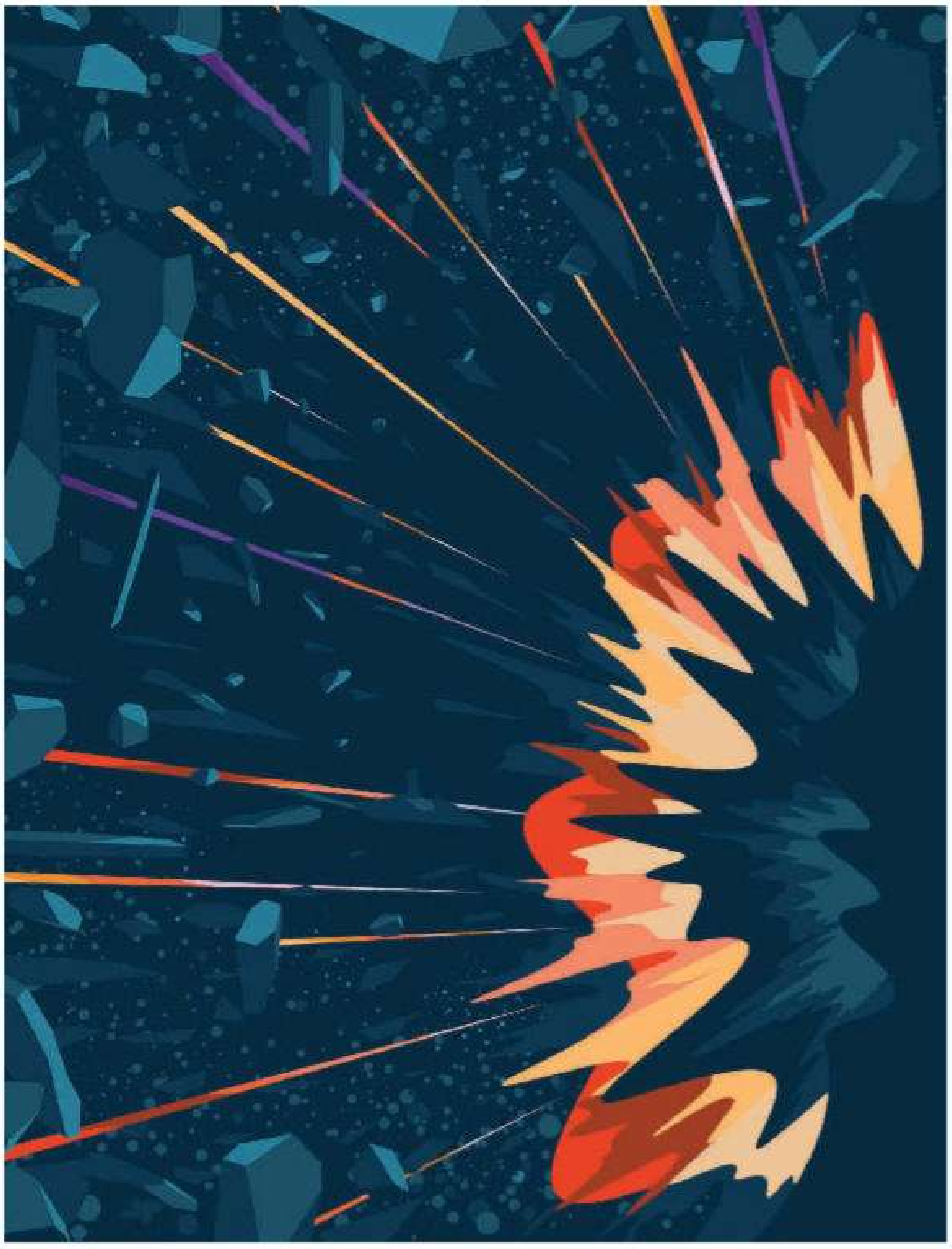
This decoupling raises questions in itself, he says, as it is unclear where the energy needed to spark the dark big bang comes from. According to Occam's razor, simpler hypotheses are always preferable. "Why have two big bangs when one is enough?" says Schmitz.

> "IN ONE DARK BIG BANG SCENARIO, YOU END UP WITH A GHASTLY DARK CANNIBAL PARTICLE"



DAVID J. WEIR

Bubbles collide in a simulation of an abrupt phase transition



"A NEWLY FOUND COSMIC HUM MAY BE A SIGNAL FROM THE MOMENT DARK MATTER FORMED"

For now, WIMPs remain a leading dark matter candidate, says Chamkaur Ghag at University College London. "It will likely be another decade at least before WIMPs can be ruled out as a favoured theory," he says. That said, Ghag keeps an open mind about more outlandish alternatives such as a second big bang. "On the face of it, there is nothing wrong with the theory," he says. "The question is whether [it] holds water and is testable."

Searching for darkzillas

Freese believes the answer is yes. She says the colliding bubbles of phase changes associated with a dark big bang would leave a distinct fingerprint of ripples in space-time called gravitational waves. She even suggests that we may have already seen these ripples.

The first gravitational wave detection was announced in 2016 by the Laser Interferometer Gravitational-Wave Observatory. Since then, there have been more than 100 others. Each is traceable to a collision between two ultradense celestial objects, like black holes and neutron stars. But there is another kind of gravitational wave signal: a background hum that is similar in form to the CMB. This could be produced by many distant black hole collisions that can't be separately resolved. Or it could be created by phase transitions in the early universe.

In June, astronomers from the North American Nanohertz Observatory for Gravitational Waves (NANOGrav) detected this gravitational wave background buzz. The signal is still too faint to determine its origin, although the safe bet is on colliding black holes, given that we know these exist. The dark big bang, however, is a credible alternative explanation, says Freese. "The [energy] scales we're talking about for the dark big bang are perfect for bubble collisions that would give you NANOGrav signals," she says. There is "huge potential" in investigating all kinds of early universe phase transitions, says Schmitz, who is part of the NANOGrav consortium. "[The dark big bang] cannot be excluded based on existing data."

NANOGrav works by measuring slight disturbances in the regular signals of rotating stars called pulsars. Careful analysis of the arrival times of these signals can betray the characteristics of the gravitational wave background, giving clues to its origin. If variations, called anisotropies, appear in the gravitational hum across the sky, then it would suggest that colliding back holes, rather than phase transitions, are responsible. "If we're lucky, then such a detection of anisotropies might be around the corner, in just a couple of years," says Schmitz.

If the gravitational wave hum remains stubbornly uniform, however, it is likely to be a signal from phase transitions in the early universe. Yet this signal could be composed of many different, overlapping phase transitions that would have to be disentangled. This could include inflation, or the phase transitions that formed the forces and particles of the standard model. For example, one such energy shift occurred when the Higgs field, which gives all particles their mass, condensed out. "There could be other phase transitions," says cosmologist Chiara Caprini at the University of Geneva, Switzerland. "We don't know what happens at higher energies."

To make sense of all this, we need more precise gravitational wave data. NANOGrav is joining forces with other pulsar timing arrays around the globe, such as the Square Kilometre Array. The European Space Agency's Laser Interferometer Space Antenna is set to launch in 2037, too. Laser beams sent between its three spacecraft flying in formation will measure gravitational waves in exquisite detail. Together, says Freese, these telescopes could observe the predicted signals from the dark big bang and even identify whether darkzillas or dark WIMPs are more likely dark matter candidates. "We have to keep an eye on the data and see if we get a fit," she says.

As the gravitational wave background comes into focus, cosmologists have their work cut out. With so many possible phase transitions on the table, they must make solid predictions in order to distinguish our furthest, darkest origin story. That sounds like thirsty work. Good job I've just put the kettle on. ▮

Stuart Clark is a consultant to New Scientist. *His latest book is* Beneath the Night: How the stars have shaped the history of humankind

NOT SO SWEET

Low-calorie sugar substitutes are so ubiquitous that you probably consume them without realising. But with controversies over their impact on our health, is there a better way to get a sweet hit, asks **David Cox**

IT WAS hard to believe I was eating a lemon. Earlier, I had let a tiny, tasteless tablet linger on my tongue, the dried powder of a fruit from the *Synsepalum dulcificum* shrub from West Africa known as the miracle berry. When I later bit on a slice of lemon, it was vivid sweetness rather than sourness that filled my mouth.

In Benin, the berry has long been used to sweeten tart foods, thanks to a protein in its pulp that temporarily activates sweet taste receptors in the mouth in the presence of acids. Now it could be destined for global greatness as a key player in our quest to find healthier ways to satisfy our sweet cravings.

We all know that too much sugar is bad for us, driving an epidemic of obesity and type 2 diabetes. So, instead, many foods and drinks contain alternatives, such as aspartame, stevia and sucralose, to provide supposedly guilt-free sweetness. Increasingly, though, these products have been embroiled in controversy. In May, the World Health Organization (WHO) advised against their use for weight control and averting type 2 diabetes – things that they had previously been thought to help with.

Now we are gaining a clearer idea of exactly how these sweeteners affect our health, and the door has opened to a new wave of plant-derived alternatives. Sweeteners based on the miracle berry, a rare sugar from figs and a new kind of sugar crystal are all vying to take the top spot. Will they provide a healthy way to sate our cravings, or do we need to rethink our relationship with sweetness altogether?

Humans have a sweet tooth, and with good reason: our ancestors needed the energy that sugary foods provide in order to survive. Until relatively recently, however, our sugar hits mostly came from ripe fruits and perhaps a bit of honey. Fast-forward to today and our diets are laden with added sugars, the main culprit being table sugar – the sucrose extracted from sugar cane and beets.

Our inability to resist the stuff comes at a heavy price for our health, which is why the WHO recommends eating less than 25 grams per day (equivalent to six teaspoons) of added sugar in our food and drink. This can be challenging, given the almost ubiquitous presence of sugar in our diet. In the US, for instance, people consume around 17 teaspoons of added sugar on average every day. "It's very important that we try to find a better alternative to sugar," says Nenad Naumovski at the University of Canberra in Australia.

Sugar-free sweetness

To address this, food companies have long turned to non-sugar alternatives that activate the body's sweet taste receptors but have few or no calories. The first artificial sweetener was the result of an accidental discovery made in the 1870s, when a chemist called Constantin Fahlberg didn't wash his hands after analysing coal tar – or so the story goes – and found that his dinner was unusually sweet. The substance responsible was saccharin, which is between 300 and 450 times sweeter than sugar.

Many other artificial sweeteners have since been discovered, including aspartame in 1965 and sucralose in 1976, as well as natural ones such as extracts from the stevia plant, used for centuries by people in South America and first commercialised in the 1970s. Most are no-calorie, although some, like aspartame, contain a few calories, and they are typically at least 100 times sweeter than the average apple or orange. There are also sweeteners derived from sugar alcohols, such as the naturally occurring sorbitol and xylitol, which are roughly as sweet as table sugar but contain less than half the calories. Globally, the sugar substitutes market is worth around $20 billion a year, and these products must undergo stringent safety tests before approval by regulatory authorities.

"They've all got different properties in terms of aftertaste, how sweet they are and their chemical make-up," says Cherie Russell at Deakin University in Melbourne. "You can make different combinations of them to be appropriate for almost any food."

Russell's research has identified sugar substitutes in a diverse range of products, not just diet soda, chewing gum and sachets for adding to coffee, as you might expect, but also yogurts, cereals, ice cream, flavoured milks and kombucha drinks. This means it is very easy to consume low-calorie sweeteners without realising it, especially as they are often used in toothpaste and mouthwash (with good reason: to avoid the use of decay-promoting sugar). One study of people who said they didn't consume low-calorie sweeteners found that nearly half of them had "unexpected exposure", indicated by the presence of sucralose in their urine. Babies can even ingest sweeteners through breast milk.

A 2022 survey of different foods and beverages worldwide conducted by Russell and her colleagues found that the use of non-sugar sweeteners in drinks is increasing, as is their use in packaged foods in many countries. Usage was typically higher in countries with policies in place to reduce sugar intake.

Replacing sugar with these alternatives, however, is far from straightforward. Sugar not only contributes to the taste of food, but its texture. It prevents biscuits from crumbling and blends with egg white to yield the creamy ›

SHUTTERSTOCK/FUSS SERGEY

> **“A microbiome altered by exposure to sweeteners can induce weight gain”**

mouthfeel of some sorbets. “Taking out just 10 per cent of the sugar and replacing it with something else causes all sorts of havoc with a biscuit,” says Naumovski. “It doesn’t colour up as well, and the texture doesn’t seem quite right.” Aspartame falls apart when heated and loses sweetness, cakes made with sucralose lack volume and stevia comes with a slightly bitter aftertaste that consumers can find unappealing. So, for all their sweetness, low-calorie sugar replacements have often had to settle for certain niches, such as flavouring diet drinks or chewing gum, or accompanying sugar rather than totally displacing it from food.

Things are equally complicated when it comes to the health impact of sweeteners. In theory, if they stop us ingesting so much sugar, they should be beneficial. However, this turns out to be a surprisingly contentious issue.

Concerns have been raised over the years about the long-term safety of the consumption of certain sweeteners. The most recent was in July, when the International Agency for Research on Cancer, part of the WHO, classified aspartame as “possibly carcinogenic to humans”, based on limited evidence that it might cause liver cancer. However, shortly afterwards, other health experts at the WHO released statements that said the safety of aspartame wasn’t a concern at the doses commonly ingested.

Yet other long-term studies of large populations have also picked up links with cancer, although these don’t prove causation. In 2022, for instance, an analysis of the NutriNet-Santé population-based cohort, which encompasses more than a decade of dietary records from 102,865 adults in France, linked higher consumption of aspartame and another sweetener, acesulfame-K, to the incidence of cancer. This, together with other similar studies, “suggests signals regarding sweeteners and increased cancer risk in humans”, says Mathilde Touvier, principal investigator of the NutriNet-Santé cohort.

Some studies also suggest that long-term consumption of sweeteners is associated with a risk of weight gain, cardiovascular disease and type 2 diabetes. One explanation is that the uncoupling of sweet taste and calories can interfere with the body’s physiological response to sugar. “The brain thinks that these sweeteners are like sugar and so produces the same amount of insulin, leading to excessive production,” says Touvier. “So, when we really need it, this insulin mechanism doesn’t work.” However, there are also suspicions that we are simply seeing reverse causation in these studies, whereby people already struggling with obesity and metabolic problems might consume more low-calorie beverages.

On the other hand, many studies, mainly in rodents, suggest that consumption of foods containing low-calorie sweeteners drives hunger and hence increased food intake. This fits with research on humans from 2019, led by Allison Sylvetsky at George Washington University in Washington DC, which found that the consumption of low-calorie sweetened beverages is associated with higher total energy and sugar intake among US children and adolescents.

To complicate things further, a 2020 study found that sucralose-containing beverages only affected the body’s glucose response when consumed along with carbohydrates. In other words, drinking a zero-calorie soda might only have an impact on our metabolism if we consume it along with fries.

Microbiome impact

Some of the connection between sweeteners and the body’s glucose response may be due to the microbes in our gut. Key evidence for this comes from a randomised controlled trial last year on 120 people, led by Jotham Suez at Johns Hopkins University in Maryland. This found that sucralose, saccharin, stevia and aspartame all significantly altered the types of bacteria in the gut and mouth as well as their activity, but only sucralose and saccharin resulted in significant blood glucose spikes. When this altered microbiome was transferred to mice that lacked intestinal microbes, it elicited a similar glucose response, showing that the metabolic impact was being driven by changes in the microbiome. “A microbiome altered by exposure to sweeteners, when transplanted into mice who have no microbiome of their own… is sufficient to induce weight gain and disruption of glucose tolerance,” says Suez. “Our studies – and work by others – show that modulation of gut bacteria by sweeteners on its own is sufficient to disrupt metabolic health, independently of uncoupling sweet taste from calories.” Exactly how an altered microbiome disrupts metabolism is an open question, says Suez, who is currently investigating this.

The upshot is that sweeteners could be affecting our health in multiple ways, and we have yet to discover one with the same appeal as sugar but none of its downsides – if such a thing exists. But the hunt continues apace in the food industry. One promising place to look is among a group of 50 or so rare sugars from certain plants, the best known being allulose. Found in small quantities in figs and raisins, this has a similar taste and sweetness to table sugar, but just 10 per cent of the calories. It also doesn’t cause blood glucose spikes, so in 2019 the US Food and Drug Administration authorised it for use in “no added sugar”

A plantation of stevia, a crop that produces a sweetener that is far more intense than sugar

NORBERTO DUARTE/AFP VIA GETTY IMAGES

products. Already produced commercially, it has been used in some energy bars and condiments, yet is still relatively expensive to make. This may change in the future: a study last month showed that a genetically modified strain of the common bacteria *E. coli* can produce allulose cheaply and at scale.

Another much-vaunted sugar alternative is monk fruit extract, a concentrated powder produced by drying the juice from the berries of a vine that grows in remote regions of China. Used for centuries in Chinese traditional medicine, the extract's sweetness comes from a substance called mogroside V, which is more than 200 times sweeter than sugar, but contains no calories. Finding a way to scale up the production of monk fruit extract has also been challenging, but the North Carolina "molecular farming" company Elo Life Systems has now developed a way to grow mogroside V directly in watermelons – with the idea being to generate it in much larger quantities.

Also emerging on the market is a product called Supplant, which is made by "upcycling" the leftover parts of arable crops such as wheat straw, using enzymes to turn the carbohdyrates into a mix of sugars and fibres. This produces a high-fibre product that tastes similar to cane sugar and has similar properties when cooked, such as caramelisation, but with half the calories and generating a lower blood sugar response.

SHUTTERSTOCK/NEW AFRICA

A rare sugar called allulose, found in figs, is a low-calorie substitute for table sugar

But perhaps we could one day get rid of sugar and its low-calorie mimics altogether, and still get a sweet hit. That is the promise of a range of sweet proteins found in the berries of various West African shrubs. These include brazzein, monellin and, the best known, miraculin, which comes from the berry that made my lemon sweet.

The miracle berry was disappearing from Benin's national cuisine, says Dèdéou Tchokponhoué at the University of Abomey-Calavi in the country. One problem is that it is a slow-growing species that can take five years to fruit, he says. However, in 2019, he and his colleagues announced a way to slash the fruiting time to just 18 months, with the aim of using the crop to help address surging rates of type 2 diabetes in Benin.

Sweet proteins

Food manufacturers elsewhere are attracted by the prospect of using miraculin or other sweet proteins in healthy but sour-tasting foods, such as plain Greek yogurt, to create the perception of sweetness. However, there are many hurdles to overcome, such as the short shelf-life of miraculin.

Genetic engineering may be one solution. Researchers at the University of Tsukuba in Japan have inserted miraculin plant genes into tomatoes. Other researchers are attempting to produce proteins such as miraculin and brazzein through fermentation by inserting their genes into microbes that can then pump out these compounds, so there is no need to cultivate the berries.

Meanwhile, at the University of Naples in Italy, Delia Picone has been studying the sweet protein monellin, first isolated from the serendipity shrub in West Africa, and believes it has better commercial potential than miraculin. "It's among the sweetest proteins, so you need just a very small amount as a sugar substitute," she says. One drawback of monellin is that it disintegrates when exposed to heat, but in 2021 Picone and her colleagues devised a way to tweak its chemical structure so that it remains intact during cooking.

Although these substances are "generally recognised as safe" by regulatory authorities, watch this space, as research on the long-term health impacts of these newer products is in its infancy, so we don't yet know if they will have similar disadvantages to more established sweeteners.

Meanwhile, researchers have been tinkering with sugar itself to reduce some of its downsides. The Israeli company Incredo has devised a way to restructure the sugar crystal by mixing it with tiny grains of silica, less than one-50th the diameter of a human hair, to make sugar dissolve faster on the tongue. This delivers an intense hit, allowing manufacturers to create lower-calorie sweet-tasting foods.

None of these developments, however, addresses the underlying problem that diets in modern high-income countries are simply too sweet, says Suez. "We're consuming way more sweetness than our body evolved to handle, whether it's caloric or non-caloric. This is why I think our number one goal, as we think about translating our research to the public, is helping people realise that we just need to consume less sweetness in general."

Russell has similar concerns. There is a real harm from developing a very sweet palate "that makes us less likely to consume foods that we know are integral to a healthy diet – whole grains, fruits, vegetables, things like that that aren't super-sweet in the way that a lot of manufactured products are", she says. "That's a huge problem for dietary patterns globally, especially for children. You get to the point where you just expect a massive sweet hit in almost everything."

When it comes to sugariness without the sugar, it seems we still have a way to go before we hit the sweet spot. ▮

David Cox is a freelance writer based in Brighton, UK

An oasis in Libya, where groundwater is a scarce commodity

SHUTTERSTOCK/PATRICK POENDL

The secret life of oases

Oases have been both refuge and lifesaver throughout human history. Now, we are discovering that they are also sources of extraordinary biodiversity, says **Rod Fensham**

IMAGINE you are in a desert. The air is dry, the landscape barren, but before you lies a teardrop-shaped pool. It is strangely lush, with sedges and tussocks of grass. Spiky succulents surround its salty shore. Peering into its crystal-clear waters, you observe various snails and furry brown domes that resemble frightened sea anemones. A shrimp-like creature paddles by. There's a sort of leech, but it is lurid green. A small fish with red eyes and blue fins swims into view. Another fish, a flat-bellied bottom dweller, darts out of some weeds, flicking a cloud of mud. All these creatures are new to science.

It may sound like a nature lover's fantasy, but this is real. It is an oasis in Australia's arid interior, a place I have been lucky enough to visit and study. What's more, it isn't so unusual. Emerging evidence reveals that oases are often crucibles of biodiversity. These little pools in vast deserts are the ultimate isolated habitat, yet their antiquity, stability and weird chemistry have made them home to extraordinary organisms found nowhere else on Earth.

Oases still have secrets to impart. The exact locations of many of them remain unmapped. Meanwhile, others are threatened by demands for groundwater, a growing peril due to climate change and increasing human populations. That's why I decided to establish the Fellowship of the Spring to save the world's oases. This may sound ambitious, but recent developments in oasis rehabilitation show it can be done. Besides, the special cultural significance of oases and their crucial role in humanity's past and future compels us to protect them.

There is something profoundly mysterious, even sacred, about water spilling from the depths of Earth in a desert landscape. Perhaps that is why the word "oasis" has such psychological power, characterising a place of safety and fertility in a barren world. Across cultures, the mineral-rich waters of these springs are bestowed with healing properties, and for millennia they were the primary treatment for human diseases and ailments. Despite the advent of modern medicine, oases remain important places for rest, for recuperation and to focus on well-being.

In humanity's deep past, oases also played a crucial role in survival. The remains of early hominins are often associated with desert springs, prompting archaeologists to suggest that they may have been critical habitats for the evolution of our species. Oases allowed trade routes to develop through the vast deserts of Asia and Africa, and they are still essential today.

Many cultures recognise oases as places of great mystical power (see "Sacred springs", page 42). In several languages, they are referred to as "eyes", perhaps because they have been seen as windows to the underworld. This is certainly the case from a geological point of view. All desert springs have their source in aquifers. Some of these hold groundwater in open cavities formed within soluble rocks, such as limestone. In others, the water lies between the grains of solid rock, including sandstone. Springs tend to form at geological structures, such as a fault or where two rock types meet, but the water may originate as rainfall in mountain ranges thousands of kilometres away from where it discharges.

> "Many cultures recognise oases as places of great mystical power"

The Great Artesian Basin in Australia, one of the largest aquifers in the world, seems to be an open system, recharged by rainfall, which then discharges through springs. In other places around the world, springs are fed by "fossil water" – with no rainfall currently entering the aquifer, the system must have been replenished during wetter climates of the distant past. One place that owes its existence to such springs is Djanet in south-east Algeria. Located in the heart of the Sahara desert, it receives an average of just 10 centimetres of rain annually. Yet, at times during the past 10,000 years, this region was a savannah watered by regular rainfall, as images of giraffes, cattle herds and flourishing human activity on local cliff faces attest. That ancient rain feeds the springs of the Sahara today.

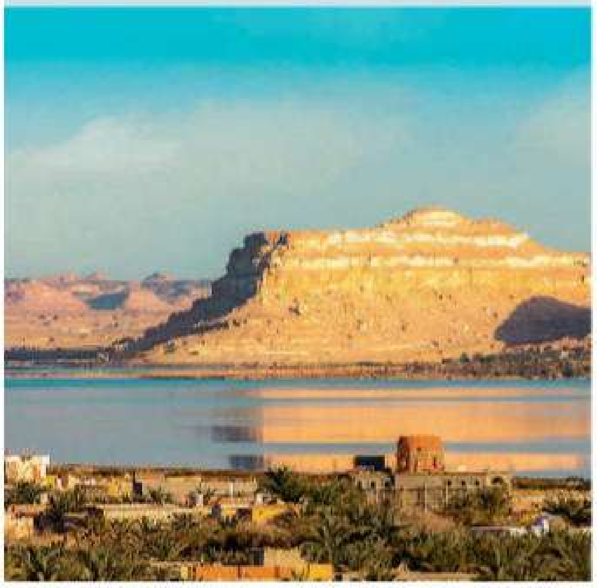
While the value of oases for human culture has a deep history, their ecological significance has only recently started to emerge. In 1912, Czech explorer Alois Musil described a "pool of stagnant water… animated by various aquatic creatures" at an oasis at Ayn al-Tamr in the desert of Iraq, and suggested that it offered the prospect of a "very interesting study of the aquatic fauna". No one has yet followed Musil's suggestion. Indeed, the vast majority of oases haven't been visited by researchers. Those that have, however,

Sacred springs

Mythologies associated with oases are remarkably similar in desert cultures around the world. The springs, which are gateways to vast, invisible subsurface realms, are often seen as spiritual connections to the underworld, inhabited by dead ancestors or supernatural beings.

The association of springs with oracles is remarkably common across many cultures. Oases are sacred for some Native American peoples, with springs said to provide access to spirits generating prophesy and prosperity. Springs had a similar function for some Indigenous Australians. Likewise, the ancient Egyptians consulted a human oracle at the Siwa oasis, which is sustained by desert springs.

One foundation of ancient Greek civilisation was the Oracle of Delphi. The supposed source of this soothsayer's power has become an enduring mystery, as during the fall of Greece, the temple at Delphi was ransacked, its riches were looted, the buildings were destroyed and the inscriptions were defiled. However, we do know that prophesies were thought to be delivered by a woman with the power to serve as the mouthpiece of the great god Apollo, and that before she commenced her work, she would bathe in a spring. Given what we know from other cultures, the spring may well be the mysterious source in the oracle myth.



SHUTTERSTOCK/MOHAMED MONIR

Siwa oasis in Egypt, where the ancient Egyptians consulted an oracle

indicate that exciting voyages of biological discovery await us in Iraq and elsewhere.

A biological survey by myself and my colleagues revealed that oases around the world provide habitats for a plethora of endemic species – specialised organisms with very restricted distributions. These include plants, flatworms, leeches, mites, crustaceans, snails, insects, spiders and fish. Our paper, published in June, documents 29 endemic species in springs at Ash Meadows in Nevada, within the Mojave desert. We found that springs at Cuatro Ciénegas, Mexico, are home to 60 endemic species, including seven species of fish, three species of turtle and a lizard found nowhere else on the planet. And at Byarri in the Great Artesian Basin, my colleagues and I have identified 36 endemic species, including the ones I described at the beginning of this article.

These local concentrations of endemic species are unrivalled by other habitats and locations. Some are adapted to the unusual salts that accumulate around the edge of mineral-rich springs. At all sites, the endemic species persist in oases not much larger than a garden pond. It is remarkable that animals that would die if left without water for even a few minutes have survived in such an isolated and tenuous habitat. Where did the specialised species come from, and how did they manage to persist in such tiny ponds amid a hostile landscape?

Genetic analysis, based on the rate at which mutations accrue during evolution, indicates that oasis-dwelling organisms diverged from their ancestors millions of years ago. This suggests that some species evolved when the continents had a different configuration and there were wet forests and streams where we now have desert. It is possible that, as these landscapes dried out, the widespread aquatic species contracted back to the springs and have survived as relics.

An alternative possibility is that improbable dispersal events occurred, allowing colonisation from moister environments. Imagine, for example, a seed germinating or an egg hatching after travelling in a dollop of wet mud on a pelican's foot.

Either of these stories of evolution and survival in tiny ponds would be miraculous. What isn't in doubt is that some springs have persisted over millions of years. Nevertheless, these ancient habitats are fragile and at risk from human activities.

A tale of decline has been well documented in Australia. For millennia, springs in the arid interior allowed Indigenous Australians to survive there. Only a few stories hint at the significance of these locations, but an abundance of stone tools leaves no doubt that the oases sustained life for many people. But when European pastoralists arrived in the 19th century, what they saw was a parched landscape barely suitable for farming sheep and cattle.

However, the springs hinted at an underground reservoir and became a window to their own demise. Holes were drilled through the rock layers, allowing the water to burst forth as gushing fountains: the Great Artesian Basin, which underlies one-fifth of Australia, had been discovered. Before long, there were thousands of boreholes and the water was directed along a network of open drains. A vast expanse of dry grassland had become productive pasture. Most of the water evaporated under the

ROBERTO ARMOCIDA/GETTY IMAGES

SHUTTERSTOCK/NEKTONOGRAPHY

Oases in Cuatro Ciénegas, Mexico (far left) and Ash Meadows in Nevada

> "In oases, the concentrations of endemic species are unrivalled by other habitats"

Australian sun and pressure in the aquifer dropped so much that, within a decade, half of the springs had diminished to a dribble and disappeared. We can only speculate at the extinction of endemic species.

The story of springs revealing aquifers, exploitation of groundwater, declining water pressure and the subsequent loss of oases has been retold time and again around the globe. As a result of climate change, population growth and economic development, demands for water are increasing. Groundwater extraction may seem like a solution, but, to succeed, it requires good planning and great care.

Road to recovery

Libya offers a cautionary example. There, water demand has reached crisis point. In 1984, work commenced on the ambitious Great Man-Made River Project, which aimed to pipe water from the fossil water aquifers of the Sahara to urban centres along the Mediterranean coast and to supply water for irrigation and industry. The project is yet to be completed and civil strife in the past decade means it has faltered. Infrastructure is falling into disrepair and water piracy is rife. Despite the dream, there is still insufficient water for household use in urban centres, let alone for the expansion of agricultural development.

If groundwater is to help meet humanity's growing need for fresh water, extraction must be sustainable. With judicious use of groundwater in deserts, it is also possible to preserve the oases and their extraordinary wildlife.

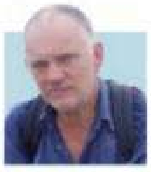
This much is clear from a major scheme currently under way in Australia. The joint public-private initiative aims to restore lost groundwater pressure in the Great Artesian Basin by fitting the old boreholes with giant taps and diverting water from the open drains into plastic pipes. This benefits farmers because the water can be directed to a network of drinking troughs at targeted locations that extend further than the old drains. Conserving water maintains aquifer pressure, which makes it easier to deliver. With the recovery in pressure, the critically important springs at Byarri have doubled in size in just 15 years.

The experience from Australia demonstrates that we can benefit from groundwater while still conserving or even restoring oases. However, a prerequisite to sustainable groundwater development globally is a thorough understanding of the hydrogeology of aquifer dynamics. We need to know whether a particular aquifer is being recharged and, if so, where the water is coming from. We need crucial information about the springs too, including why they occur where they do. And we also need to know about the ecosystems we are trying to conserve. Currently, we only have limited systematic surveys mapping where oases occur and an even cruder understanding of their biological value.

Pondering this problem during a covid-19 lockdown, I decided that there was something I could do to help. So, in 2020, I met people online who shared my vision, and together we formed the Fellowship of the Spring. We are now an eclectic group of 30 geologists, biologists, hydrologists, anthropologists, archaeologists and groundwater managers from 16 countries, including Libya, Iraq and Afghanistan, war-ravaged nations where water supply is a major issue. Our mission is to document springs, learn from the stories of local people and share information and experience to ensure the sustainable management of aquifers.

The Fellowship of the Spring has already been busy. Some achievements so far include: an inventory of springs in Namibia; sharing information about the impacts of lithium mining on oases with members of a community group in Chile's Atacama desert; and revealing the significance and decline of springs along the Abu Jir fault in Iraq, which stretches 500 kilometres and has formed a divide between the eastern and western hemispheres since the dawn of human civilisation. We will continue to raise awareness of springs and what is at stake if they are lost.

Desert springs or oases have empowered people throughout history and across cultures. Now, we know that they are also remarkable crucibles of evolution. My hope is that the power and magic of oases can be harnessed again to protect them. ▮



Rod Fensham is a botanist at the University of Queensland, Australia. He has been studying Australian oases for 25 years

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The science of cooking

Against the grain

The secret to a perfect, golden loaf (or tasty beer) is an enzyme in malt. And making your own is easy, says **Sam Wong**

Sam Wong is assistant news editor and self-appointed chief gourmand at New Scientist. Follow him @samwong1

What you need

Whole barley grains
A kitchen tray or baking sheet

The science of cooking appears every four weeks

Next week

60-second psychology

EVER since the time of ancient Egypt, people have used sprouted cereal grains – malt – to make beer. For bakers, malt is also a secret ingredient that helps bread rise perfectly and develop an attractive brown crust.

Cereal grains are packed with starch, a complex carbohydrate made up of long, branching chains of glucose molecules. It is a source of stored energy for the embryonic plant to grow. But in order for cells to make use of that energy, the starch has to be broken down into small sugars consisting of one or two glucose molecules.

In the 19th century, chemists discovered that malted barley contains a chemical with the power to convert starch into glucose. This was the first enzyme to be discovered, and they named it diastase; today, we call it amylase. When seeds germinate, they produce these amylase enzymes to break down starch.

Yeast also needs simple sugars, which it ferments to produce alcohol. It has its own amylase enzymes for breaking down starch, but beer brewers rely on malt because it provides much more amylase, and therefore more food for the yeast.

Malt is useful to bakers for the same reason: amylase enzymes provide a ready source of food for the yeast that leavens bread. This is particularly helpful if you have a long proofing stage – for example, if you are fermenting pizza dough in the fridge for several days.

The extra sugars in the dough help develop a nice brown colour on the outside of buns or bagels.

SHUTTERSTOCK/IURII OSADCHI

You can buy diastatic malt powder from baking suppliers. They may also sell a non-diastatic version, but this doesn't contain active enzymes – it is just for flavour.

Or, you can buy whole barley grains and make your own malt. First, soak them in cold water overnight. In the morning, skim off any floating detritus, then drain the grains and spread them out on a tray. That evening, repeat this process: soak overnight, drain and spread out. By now, you may see rootlets growing out of the grains (pictured). Spray them with water and turn occasionally to expose them to air.

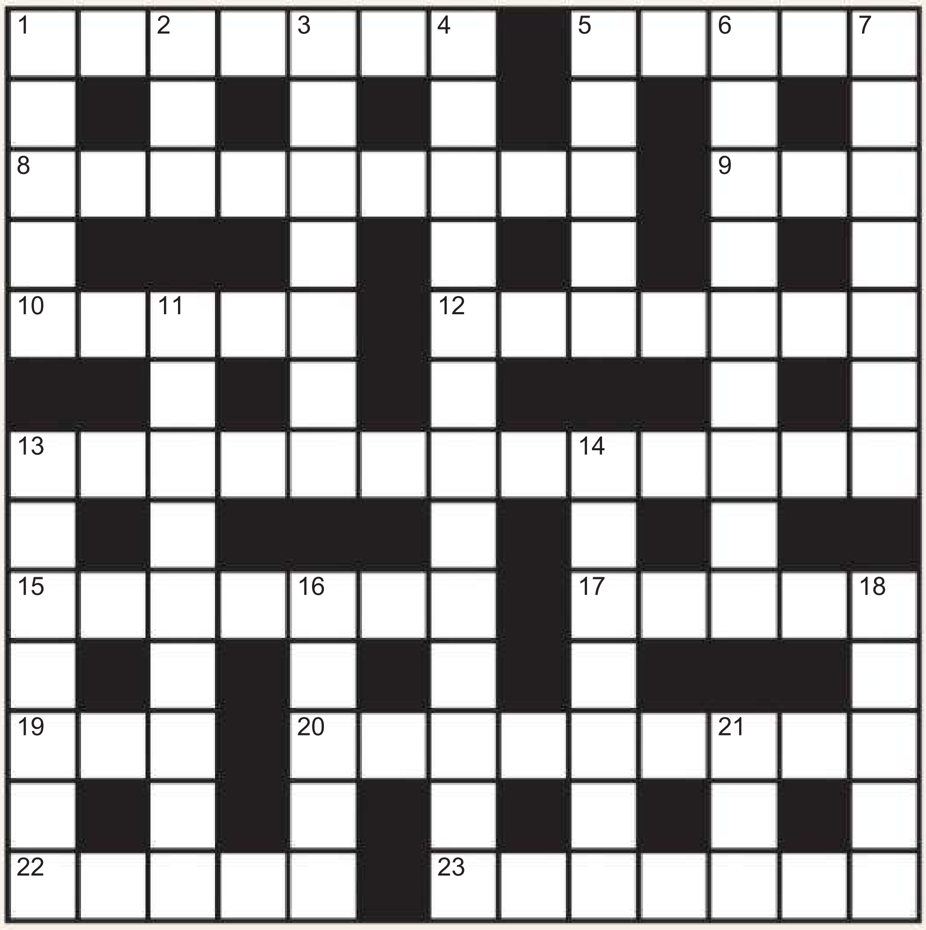
In barley, the acrospire (a plant's shoot), starts growing inside the kernel. Once a day, cut a single grain lengthwise to check its growth. When the acrospire is nearly as long as the grain's kernel, dry the grains to stop them growing. Place them in a warm spot – near a radiator, say – but not too warm, as the enzymes will be destroyed above 50°C (122°F).

Once they are completely dry, grind the grains with a mortar and pestle or spice mill to make diastatic malt powder. Try adding a small amount – about 1 per cent of the weight of the flour – the next time you make bread.

If you are a home brewer, you might try roasting your malt and adding it to flavour beer. Brewers use base malt, containing active enzymes, and roasted malt. ▮

These articles are posted each week at newscientist.com/maker

Cryptic crossword #122 *Set by Trurl*



Scribble zone

Answers and the next quick crossword next week

ACROSS

1 Minor celebrity's sore (7)
5 Obtain leave for commencement (3-2)
8 Broken rule, again, being a pain (9)
9 Brit abroad coming back to get clean (3)
10 Gasket's dry, blowing top (1-4)
12 Late adjustment to rule forbidding fighting in lumps (7)
13 Worker who's apparently absent – a market's meant to have one (9,4)
15 Functionary who might suspend you? (7)
17 Prepare for online gag (5)
19 Gravity missing from components used in building constellation (3)
20 Tom Nelson, possibly, is drowsy (9)
22 Fabric made from sunshine and elements of air (5)
23 They work with Threads and don't require so much, finishing early (7)

DOWN

1 Throw away game to get another! (5)
2 I see you speaking where acute cases are seen (3)
3 Cooking, one grates mace, perhaps (4,3)
4 Carelessly abandon German guy who picked up trash (3-3-4,3)
5 Influential organ in European country, lacking dash (5)
6 One adult man lost somewhere in India (5,4)
7 Arranged for picture after surgery – unsympathetic! (7)
11 Like Edison, perhaps, making list? (9)
13 Wheezer's remedy when her nail is broken (7)
14 Eeyore's miserable – it's not nice to see (7)
16 Particle that's minute, on front end of plane, heading upwards (5)
18 Green strokes matter, around two times (5)
21 Evenly, oddly, it's fishy! (3)

Our crosswords are now solvable online
newscientist.com/crosswords

Quick quiz #227

set by Bethan Ackerley

1 The observation that, within genera of mammals and birds, those species in colder climates grow to larger sizes is known as what?

2 Which complex aromatic polymer forms much of the structure of wood, alongside cellulose?

3 Where would you find adipocere?

4 Who first confirmed James Clerk Maxwell's equations of electromagnetism in 1887?

5 When is Yuri's night, a celebration of milestones in space exploration, held each year?

Answers on page 47

Headscratcher

set by Alison Kiddle

#247 Bargain birthday badges

Grandad has always been a bit of a cheapskate – and a little eccentric too. He's sick and tired of buying birthday badges every year for his increasingly large family of grandchildren, all of whom have different birthdays.

"Can't we just use multiplication to save us buying quite so many badges?" he suggested. "Look, last year, Suzy turned 2 and Billy turned 7, so instead of wasting money on a badge for Joey's 14th, we could have just put the 2 and 7 together. We would all know that it means 2 × 7."

The rest of the family weren't enthusiastic, so Grandad sat down to work out just how much they would save in badges if they introduced the scheme (with the savings going straight into everyone's piggy banks).

How few badges does Grandad need to buy if he wants to be able to make a set for any birthday from 1 to 21?

Solution next week

On the small side

Is there a limit to how small an adult arthropod can be? If so, what is the reason for the limit?

David Bortin
Whittier, California, US
Arthropods, like everything else, must have a theoretical lower size limit. Consider the following points.

Quantum physicists know that no physical object can have a dimension smaller than a Planck length, or about 1.6×10^{-35} metres.

Organic chemists know that living tissue must contain carbon-based macromolecules, such as DNA, which are typically around 0.001 micrometres in diameter.

Semanticists don't all agree whether a virus particle is living or just a complicated complex of macromolecules, but because of the covid-19 pandemic, we all know what they look like: typically, they are around 0.5 micrometres in diameter, and sometimes as small as 0.02 micrometres.

> "There are marine arthropods just 85 to 100 micrometres long, and terrestrial insects like fairyflies that are only slightly longer"

Microbiologists know that the smallest incontrovertibly living organisms are bacteria – typically around 1 micrometre in diameter.

Zoologists know that some arthropods are among the tiniest multicellular animals. They include insects, spiders and crustaceans; all have segmented bodies, jointed limbs and a shell of chitin that is shed periodically.

There are marine arthropods just 85 to 100 micrometres long and terrestrial insects (fairyflies) that are only slightly longer. In terms of body mass or volume, the fairyfly might actually be the smallest.

Considering the complexity required to qualify as a true arthropod, this is surely close to the theoretical limit, but no one can know for sure if the smallest – either extant or theoretical – has actually been found. These organisms are near the limit of visibility to the unaided human eye, although under ideal conditions, objects down to about 35 micrometres can be resolved.

Mark Thompson
Tewkesbury, Gloucestershire, UK
There isn't a strict limit to how small an adult arthropod can be, but there are practical constraints imposed by their biology and physiology.

The smallest adult arthropods are often microscopic, and can be less than 0.1 millimetres in length. These organisms have evolved specialised adaptations that allow them to function at such small scales. For example, they have simple respiratory systems that rely on passive diffusion and may have reduced or simplified organ systems.

However, there are limits to how small arthropods can become due to various factors. These include cell size and function. Cells have a minimum size required for basic functions, such as DNA replication and protein synthesis. This is a constraint on the organism's size.

There are also respiratory limitations. As arthropods get smaller, their surface area-to-volume ratio increases, making it harder for them to exchange gases like oxygen and carbon dioxide with their environment. This can limit how small they can be while still obtaining enough oxygen to survive.

The smallest known adult arthropods may be *Stygotantulus stocki*, which are parasitic on Harpacticoid planktonic copepods. You could fit 50,000 of them on a teaspoon.

PICTURE THIS IMAGES/ALAMY

What triggers cicadas to make noises in unison, then suddenly go silent all at once?

This week's new questions

Sound of the summer **What triggers cicadas to make noises in unison, then go silent periodically?** ***T. Bard****, Tascott, New South Wales, Australia*

Bubbling up **Does putting a teaspoon into an open bottle of champagne really prevent it from losing its fizz, and if so, why?** ***Wolfgang Schady****, Bath, UK*

Mixing it up

The surface of the oceans is warming, but there must be lots of cold water in the depths. Couldn't we just stick a giant egg whisk down there and stir things up a bit to solve the warming problem?

Eric Kvaalen
Les Essarts-le-Roi, France
The cold water at depth is denser than the warm water higher up, and therefore it requires energy to mix the layers. If you bring cold water up using energy, it will then fall right back down to the depths unless it is mixed with warm water. Obviously, to have a noticeable effect, it would require huge amounts of energy input. This, of course, would be a huge problem.

Alice Kay
via Facebook
I used to wonder about this too. I once thought that a telescopic Archimedes screw – an ancient kind of water pump – that was a couple of hundred metres long and powered by wind turbines mounted on ships might give us some extra breathing space to sort out destructive weather patterns, which are based on ocean currents.

But then I looked at how much water we would need to shift, and how big the oceans are, and my maths wasn't up to working out how many thousands (hundreds of thousands?) of these screws we would need.

That's not to mention the inevitable damage to marine life, the dangerous exchange of gases that are down there, the exposed

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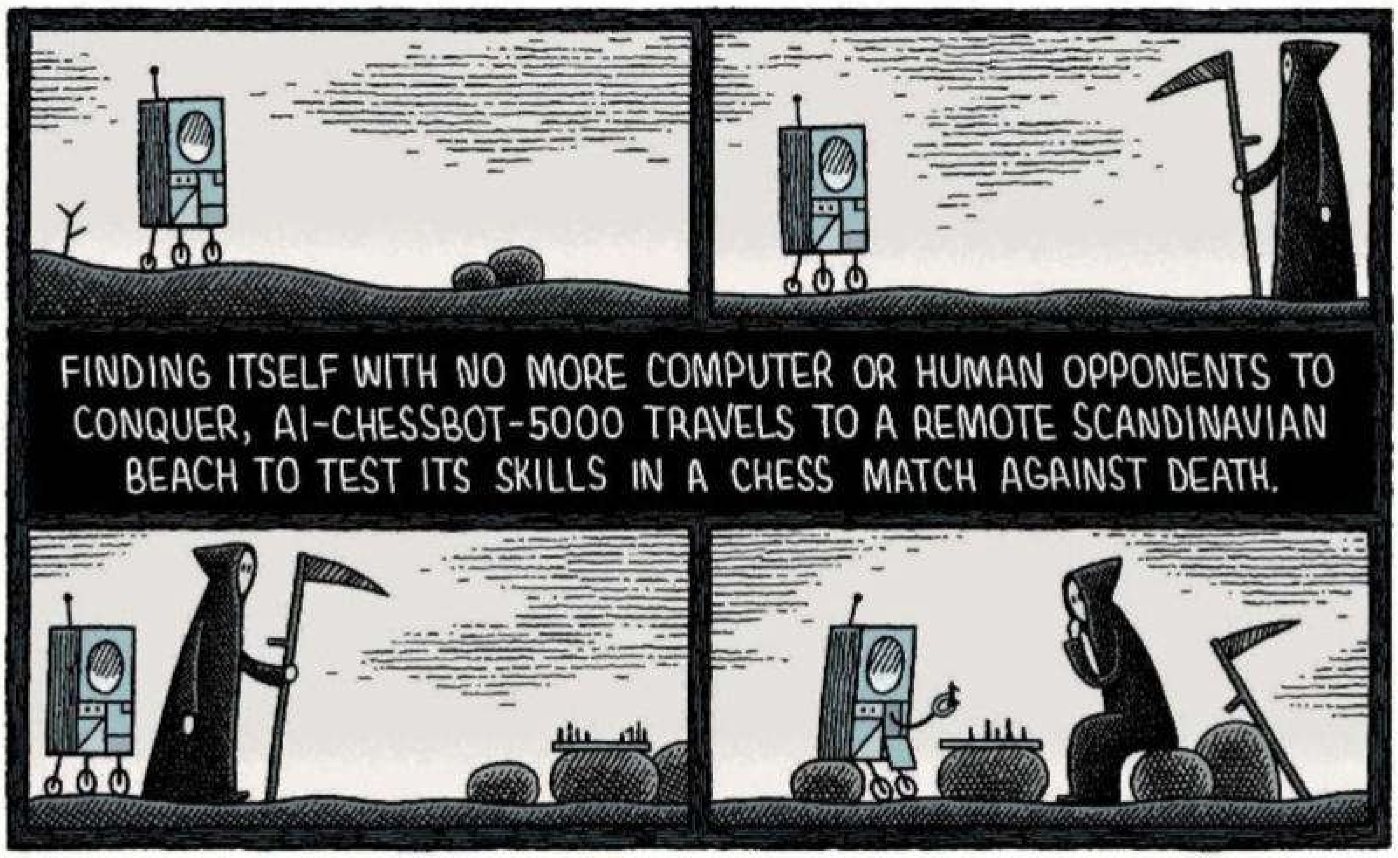

FINDING ITSELF WITH NO MORE COMPUTER OR HUMAN OPPONENTS TO CONQUER, AI-CHESSBOT-5000 TRAVELS TO A REMOTE SCANDINAVIAN BEACH TO TEST ITS SKILLS IN A CHESS MATCH AGAINST DEATH.

nature of where these screws would need to be situated and the over-optimistic hope that somehow saline water and fresh water will decide to stay where they are put.

John Hayes
via Facebook
Making the oceans a homogeneous temperature would switch off the great currents that circulate seawater around the globe.

This would be disastrous to much sea life, as many species are adapted to certain temperatures, and nutrients and oxygen are transported on such currents.

> **"Making the oceans a homogenous temperature would switch off the currents that circulate seawater around the globe"**

It would also cause huge climatic effects on land, as the currents transport warmth and moisture from the tropics towards the polar regions.

Kevin Parker
via Twitter
Rather than a whisk, the answer, of course, is a supergiant version of the bubble blowers found in fish tanks.

Itchy and scratchy

Are gnats attracted to eyeballs, or are those near our eyes simply the ones we notice most?

Mike Follows
Sutton Coldfield,
West Midlands, UK
The term gnat is a loose description for many species of tiny flying insects. I was surprised to learn that some entomologists exclude tiny biting insects like the black fly (*Simuliidae*) and biting midges (*Ceratopogonidae*) from their definition of what a gnat is.

Eye gnats, or eye flies, are part of the genus *Liohippelates* in the Americas and *Siphunculina* in parts of Asia. These are part of a biological family of insects known as grass flies, which are sometimes called frit flies (not to be confused with fruit flies).

It is eye gnats that are attracted to lachrymal secretions (tears). I can imagine that the irritation could be extreme enough to bring tears to your eyes, which is likely to make things worse.

The problem is that eye gnats are attracted to a variety of animal secretions, including dung, as well as open wounds. This means pathogens can stick to the insects, leading to the transmission of diseases like human acute conjunctivitis (pink eye), Brazilian purpuric fever and yaws, a skin infection seen in the Caribbean and parts of South America.

Eye flies can occasionally and inadvertently injure the eye. A 1976 study found that an eye fly *(Siphunculina funicola)* once became trapped in the eyelid of a 15-year-old Indonesian girl, where it became entombed in a cyst.

They can transmit disease among animals, including acute bovine mastitis and vesicular stomatitis, which presents as akin to foot-and-mouth disease. ▮

Answers

Quick quiz #227
Answers

1 Bergmann's rule
2 Lignin
3 On dead bodies. Also known as grave wax, it is a soap-like substance created when body fat is broken down by anaerobic bacteria
4 Heinrich Hertz
5 12 April, the date when cosmonaut Yuri Gagarin became the first person to fly in space

Quick crossword #145 *Answers*

ACROSS 1 Broken leg, **6** Cysts, **9** Spindle, **10** Lanolin, **11** Louis, **12** Life cycle, **13** Cotton gin, **15** Lance, **16** Locke, **18** Echovirus, **20** Sargassum, **23** Infer, **25** Residua, **26** Urinate, **27** Meson, **28** Enteritis

DOWN 1 Basal, **2** Oviduct, **3** Endoscope, **4** Lyell, **5** Goldfinch, **6** Conic, **7** Silicon, **8** Senseless, **13** Colostrum, **14** Greyscale, **15** Lavoisier, **17** Corpses, **19** Refract, **21** Add-on, **22** Moult, **24** Reeds

#246 Monoglots
Solution

The greatest possible number of monolingual delegates is 625. This requires 125 monolingual speakers of each language and 375 who speak all five languages.

Each language is spoken by 500 people. With five languages, that means there are 2500 language skills to be distributed among the 1000 delegates. If more than 625 delegates speak just one language, then the total count can't add to 2500, even if the rest speak five languages each.

Wrong, wrong, wrong

Research shows there was too much wrong in medical practice in France, for at least a decade. And – or maybe but – earlier research indicates that there is way too much wrong in medical research, in general, everywhere.

The *Journal of Patient Safety* has a new report called "Insurance claims for wrong-side, wrong-organ, wrong-procedure, or wrong-person surgical errors: A retrospective study for 10 years". Something is a little off even with that title. A year off. The text tells of examining the claims filed with a medical liability insurance company in France "during a period of 11 years, from January 1, 2007, to December 31, 2017". Feedback notes that the name of the insurance company is "Sham".

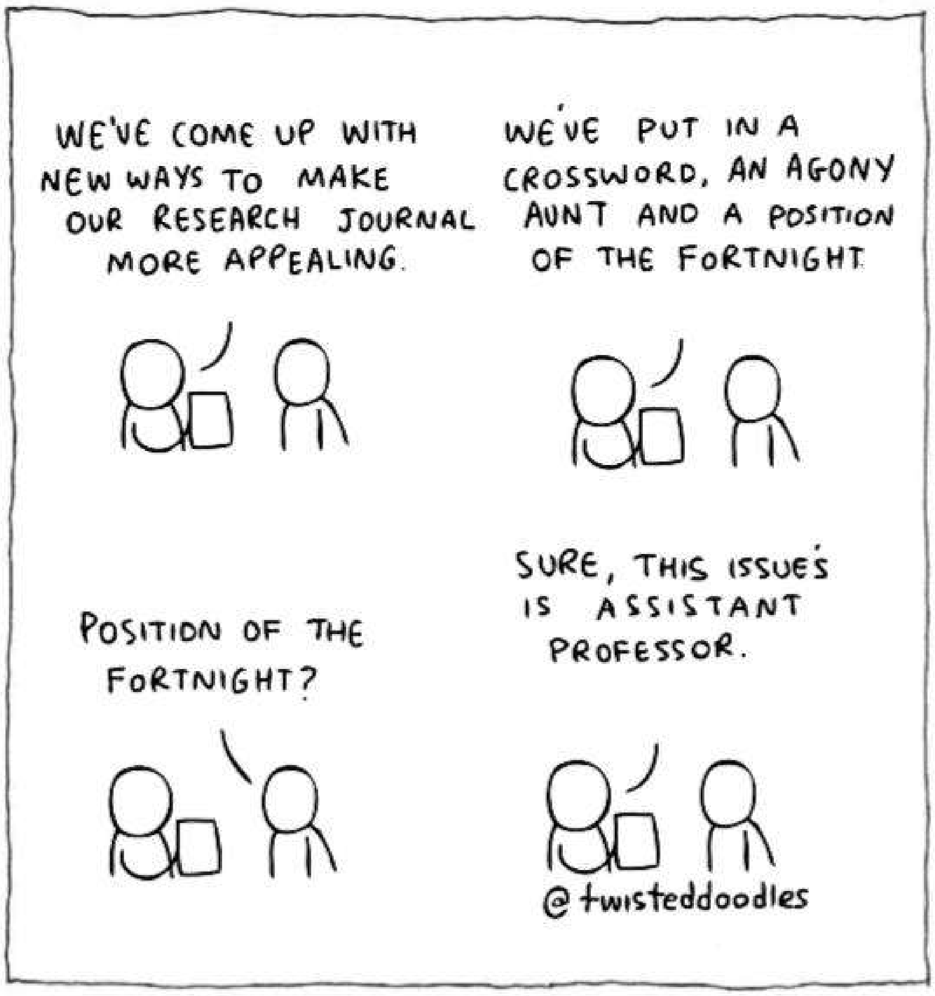
The story is far from bleak, though. The report shows the problem to be widespread but not deep, and almost entirely fixable. The key passage says: "Wrong-side, wrong-organ, wrong-procedure, or wrong-person surgical errors are rare but fully preventable by the implementation of a safety culture."

Medicine is a difficult undertaking, with uncertainty lurking always, everywhere. Medical practitioners and patients alike were shocked in 2005 when John Ioannidis, then based both at the University of Ioannina School of Medicine in Greece and at Tufts University School of Medicine in Massachusetts, published a shocker of a paper in *PLoS Medicine* called "Why most published research findings are false".

But – or maybe and – that shaking was itself a little shaken in 2022 when Ioannidis published an update with the title "Correction: Why most published research findings are false". The correction was small, adding parentheses that had been missing from an equation in Table 2 of the original paper.

And maybe almost everything is okay, mostly. That is the quick take from a US study published in 2013 in response to Ioannidis's original paper. It is called "Empirical estimates suggest most published medical research is true".

Twisteddoodles *for New Scientist*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Sinus fiction

Sinus problems afflict many people, yet sinuses receive not nearly as much literary or scientific acclaim as hearts, brains, lungs, hands, feet, genitals and other body regions. Their uncelebrity perhaps affects how much acclaim and research funding is applied to sinuses and sinus issues.

Fiction books explicitly about sinus problems are rare. The most clearly labelled book of this kind is a 59-pager called *Sinus* by Naema Gabriel, published in 2013. Google translates the summary on the author's website thusly: "Naema Gabriel tells the story of a girl who, alongside her manic-depressive mother, somehow becomes a woman despite everything." (Disclosure: Feedback hasn't read the novel, but expects that the book is faithful, one way or another, to its title.)

The non-fiction literary scene is less enthralling. Much of the medical research literature would strike critics and casual readers alike as dry, not much to sneeze at, something of a void, maybe something to avoid. One of the few – and most – exciting sinus adventure publications is Robert Caughey, Mark Jameson, Charlie Gross and Joseph Han's 1995 thriller "Anatomic risk factors for sinus disease: Fact or fiction?". Its level of excitement is low, even laconic, as is evident in the official plot summary: "Sinonasal anatomic variants have been postulated as a risk factor for sinus disease. Therefore, a study was conducted to examine the correlation of sinus disease to septal deviation, concha bullosa, and infraorbital ethmoid cells."

This dearth of popularity, this sinus of excitement, can be corrected. Feedback is compiling a list of novels, movies and videos in which somebody's sinus ailments are dominantly central to the plot. If you know of a work of fiction that should be on the list, please send basic info about it to: "Sinus Fiction" c/o Feedback.

Possibility studies

In the premier issue of the new scholarly journal *Possibility Studies & Society*, the managing editor, Vlad P. Glăveanu, gives what he says is "a manifesto" about what is possible in the journal. He manifestoises about the "shift of focus from being to becoming, from what is to what could be".

The work is a jargon-filled festival, brimming with the locus of possibility, the relational space of action, new affordances, sociogenetically long histories, radical open-endedness, the imperativeness of an ethics of possibility, and other alphabetical phrases.

One of the possibility studies in the debut issue is "Possibilities are quantum" by Federico Faggin, who lists only one affiliation for himself: the Federico and Elvia Faggin Foundation, located in California.

Faggin explains that "creative agents must be purely quantum systems interacting with quantum-and-classical living organisms that in turn interact classically with each other and with the environment". Feedback notes the possibility that this statement makes some kind of sense.

Faggin is a retired electrical engineer. He is credited with designing an early microprocessor chip, the Intel 4004, which made a lot of money. It is possible that this financial success is what gave Faggin unique insights about the interaction of creative agents, quantum systems, classical systems and the environment. ▮

Marc Abrahams

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